CALIFORNIA FISH AND GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

VOLUME 43 OCTOBER, 1957 NUMBER 4

California Fish and Game is a journal devoted to the conservation of wildlife. Its contents may be reproduced elsewhere provided credit is given the authors and the California Department of Fish and Game.

The free mailing list is limited by budgetary considerations to persons who can make professional use of the material and to libraries, scientific institutions, and conservation agencies. Individuals must state their affiliation and position when submitting their applications. Subscriptions must be renewed annually by returning the postcard enclosed with each October issue. Subscribers are asked to report changes in address without delay.

Please direct correspondence to:

LEO SHAPOVALOV, *Editor*
Department of Fish and Game
722 Capitol Avenue
Sacramento 14, California

Individuals and organizations who do not qualify for the free mailing list may subscribe at a rate of $2 per year or obtain individual issues for $0.75 per copy by placing their orders with the Printing Division, Documents Section, Sacramento 14, California. Money orders or checks should be made out to Printing Division, Documents Section.

CALIFORNIA FISH AND GAME

VOLUME 43 OCTOBER, 1957 NUMBER 4

Published Quarterly by the

CALIFORNIA DEPARTMENT OF FISH AND GAME

SACRAMENTO

TABLE OF CONTENTS

FOOD HABITS OF THE KING SALMON, *ONCORHYNCHUS TSHAWYTSCHA* (WALBAUM), IN THE VICINITY OF SAN FRANCISCO, CALIFORNIA[1]

TERRENCE J. MERKEL
Georgia Game and Fish Commission
Clayton, Georgia

INTRODUCTION

The king salmon, *Oncorhynchus tshawytscha* (Walbaum), is an important commercial and game fish native to the Pacific Coast of North America. Its range, according to Roedel (1953), extends from southern California to Alaska, and then southward along the coast of Asia to the Amur River and Japan. This species is known by a number of names, including chinook salmon, quinnat salmon, spring salmon, and tyee salmon. Like other species of Pacific salmons in the genus *Oncorhynchus*, king salmon are anadromous, spending part of their life in the ocean, and entering streams to spawn. Spawning takes place in the late summer, fall, or winter, the eggs being deposited in gravel beds. Shortly thereafter the parents invariably die. The young emerge from the gravel by late winter or early spring and migrate to the ocean, usually during the first year of life, although a few remain in fresh water until their second year. Most king salmon mature at 3, 4, or 5 years of age.

Although much has been brought to light concerning the life of the king salmon in fresh water, relatively little is known of its life in the ocean.

Several studies of the food habits of ocean-caught king salmon have been made. Heg and Van Hyning (1951) examined the stomachs of 107 king salmon captured off the coast of Oregon and found that herring, unidentified clupeids, anchovies, sand lance, and euphausiids were the dominant foods. Silliman (1941) showed that specimens taken off Washington between April and November of 1938 had eaten mainly sardines, herring, smelt, anchovies, rockfish, and euphausiids. Chapman (1936) investigated the food habits of king salmon captured off Washington during the summer of 1936. He found that the most important foods, by weight, of 129 specimens from Swiftsure Bank, examined between July 13 and July 26, were sardines, herring, and euphausiids, in the order named. In addition, Chapman found that 105 specimens taken between Quillayute and about 15 miles south of Grays Harbor and examined between August 16 and September 6 had eaten mostly sardines. Pritchard and Tester (1944) studied the food of 1,383 king salmon captured in British Columbia waters over a period of

[1] Submitted for publication May, 1957. This work was performed in partial fulfillment of the requirement for a Master of Science Degree, University of California, Berkeley.

2—59164

three years, and noted that the main foods were herring and sand lance; also eaten were sardines, anchovies, capelin, surf smelt, eulachon, sticklebacks, whiting, tomcod, graycod, yellow shiner, sandfish, rockfish, wolf-eel, squid, amphipods, euphausiids, pandalids, and crab larvae. Gilbert (1913), in reference to the food of specimens taken off British Columbia, stated that where the sand lance is plentiful in the Straits of Juan de Fuca it is practically the only food eaten, but that none was observed in the stomachs of specimens from Swiftsure Bank, where the dominant food was the euphausiid, *Thysanöessa spinifera*, followed by smelt, herring, and other fishes. Milne (1955) found that herring was the dominant food of 97 king salmon captured off the southwest coast of Vancouver Island between June 29 and August 2, 1943. Fraser (1946) observed that young specimens from British Columbia had eaten herring, euphausiids, amphipods, cypris larvae, ostracods, small squid, and ascidian larvae. Foskett (1951) noted that herring, crustaceans, mollusks, and insects were consumed by young king salmon from Brandon Island, British Columbia. Senter (1940) reported that king salmon from the Icy Straits region of Alaska had eaten mostly herring, with an occasional smelt or candlefish.

No detailed study of the food habits of king salmon taken off the coast of California has been made heretofore. California Commissioners of Fisheries (1877) indicated that king salmon in San Francisco Bay feed on "smelts and other small fish." Whitney (1893), referring to the food of specimens caught in Monterey and Carmel bays, wrote, "I have found in the stomachs a great variety of small fish, more squid than anything else, next sardines and anchovies, with smelt, tomcod, shad, and varieties of small rock fish." Whitney also mentioned observing salmon with their mouths open passing through large masses of shrimps and finding their stomachs full of shrimps at times. Snyder (1924) reported that young king salmon 71 to 129 millimeters in length, taken at Monterey Bay, Half Moon Bay, and Lime Point, had eaten small fish, crustacea, annelids, small pelagic eggs, protozoa, diatoms, and a variety of insects.

The purpose of the present study was to determine the food habits of troll-caught king salmon from the vicinity of San Francisco.

ACKNOWLEDGMENTS

The writer wishes to extend his sincere thanks to the following persons who aided in the completion of this work: Mr. Donald H. Fry, Jr., of the California Department of Fish and Game, and Dr. Paul R. Needham of the University of California, for guidance throughout the course of this study; Mr. Eldon P. Hughes and Mr. Howard McCully of the California Department of Fish and Game, and Dr. A. Starker Leopold of the University of California, for information and advice; Dr. Cadet H. Hand and Dr. Robert L. Usinger of the University of California for critical review of the manuscript; Mr. Julius B. Phillips of the California Department of Fish and Game for identification of the rockfishes; Mr. Edward Brinton of the Scripps Institution of Oceanography for identification of the euphausiids; Dr. Ralph I. Smith of the University of California for identification of the polychaetes; personnel of the Department of Ichthyology, California Academy of Sciences, for assistance in identifying many of the fishes; and Mr.

William F. Taylor and Mrs. Emily Reid for assistance with the drawings.

Special thanks are due the San Francisco Tyee Club for financial support of this study.

The writer is particularly indebted to the salmon party boat operators of the Berkeley Yacht Harbor for their generous cooperation in collecting stomachs.

METHODS AND MATERIALS

Stomachs were obtained by sampling the catch of the salmon party boats which operate from the Berkeley Yacht Harbor on San Francisco Bay. These boats take salmon by trolling, and fish almost entirely within an area bounded on the north by Point Reyes, on the west by the Farallon Islands, and on the south by Point San Pedro (Figure 1). The king salmon is the main object of the fishery. Silver salmon (*Oncorhynchus kisutch*), pink salmon (*O. gorbuscha*), and other fishes are taken occasionally.

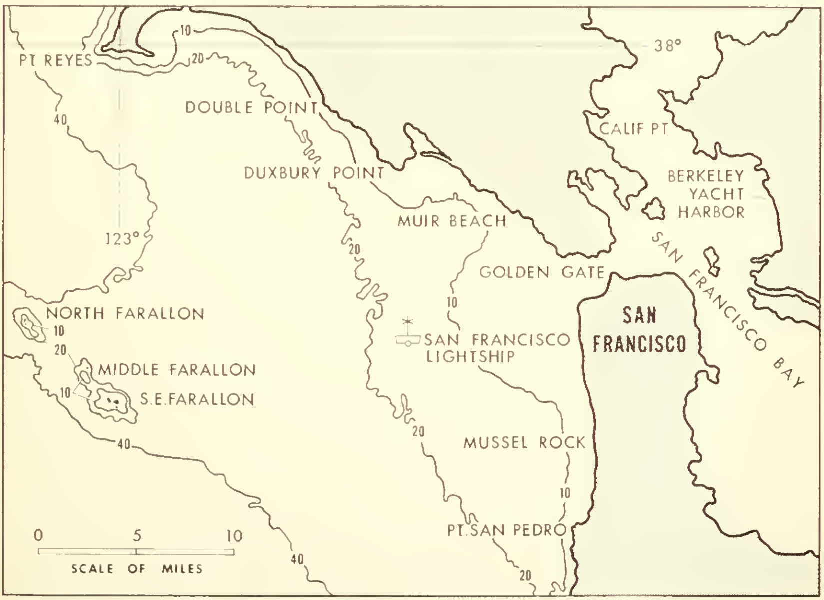

FIGURE 1. Map of the fishing grounds of salmon party boats which operate from ports on San Francisco Bay. Depths are in fathoms.

The salmon are landed either dressed with head on, or in the round, depending on whether the party boat operator cleans the fish for his customers. Most of the stomachs used in this study were from salmon brought ashore in the round, and then cleaned by the writer. However, on a number of occasions the boat operators, at the writer's request, saved the stomachs of salmon which they had cleaned for their customers. The boat operators were asked to select the stomachs at random, rather than to pick out only those which appeared to contain food, and to save the entire digestive tract so that the species of salmon involved

could later be determined by a count of the pyloric caeca. Whenever possible the gonads were also collected.

Each stomach was preserved separately in a 10 percent solution of formalin, with the corresponding gonads and a label giving the date and locality of capture, lure or bait used, name of party boat, and fork length. In order to insure accuracy of the data, the locality of capture was always obtained from the boat operator on whose vessel the salmon was taken, rather than from the angler who caught the fish. The locality of capture of many specimens could not be determined because the boats often trolled for a distance of several miles, catching the fish at various points along the way. The fork length of each salmon was measured in a straight line from the tip of the snout to the center of the fork of the tail.

A total of 1,004 king salmon stomachs was collected between October 5, 1954, and October 6, 1955, excluding the closed fishing season—November 15 to February 11. Generally stomachs were secured on at least two days of each week during the entire collecting period. Except for October and November of 1954, an average of approximately 20 stomachs was collected each week.

An idea of the distribution of the entire sample may be gained from the fact that the salmon utilized in this study were taken on 121 days by 25 boats, and 214 boat days were involved. These salmon ranged from 13.50 to 41.00 inches in fork length, and averaged 24.65 inches. Table 1 gives the distribution of the sample and the sizes of the salmon, by month of capture. That the mean fork lengths of the February, March, October, and November salmon were somewhat less than those of specimens captured in other months was due to a change in the State of California angling regulations. At the time this study was initiated, in October of 1954, each angler was permitted to take one ocean-caught salmon under the minimum size limit of 22 inches in total length (roughly equivalent to 20.25 inches in fork length). However, on March 10, 1955, a regulation prohibiting the taking of any ocean-caught salmon less than 22 inches in total length went into effect.

In the laboratory the contents were removed from the stomach, and the food organisms were grouped according to the lowest category to which they could be identified. Each group of organisms was placed on blotting paper for one minute in order to remove excess moisture, and the volume was determined by water displacement in a graduated cylinder. Then the number of individuals in each group was determined. The total length of any undigested fish or crustacean or the body length of any undigested cephalopod was recorded. Items positively identified as bait were not considered in this analysis.

Partly digested fishes were often identified by vertebral characteristics. In this connection, Clothier's (1950) work on the vertebral characters of southern California fishes proved most useful.

Data were summarized by the aggregate volume method as described by Martin, Gensch, and Brown (1946). The number and percentage of stomachs in which each item occurred, and the total number of individuals of each item were calculated for the entire sample. Frequency of occurrence was also used to compare the food habits of different sizes of salmon.

TABLE 1

Data Pertaining to the Distribution of the Sample, and the Sizes of the Salmon, According to Month of Capture

Month and year	Number of days on which stomachs were collected	Number of boats from which stomachs were obtained	Number of boat days	Number of stomachs collected*	Fork length (inches)	
					Mean	Range
February, 1955	5	6	9	61	21.63	18.25-27.50
March, 1955	12	5	11	89	22.41	16.25-31.75
April, 1955	13	9	27	93	24.70	19.75-32.00
May, 1955	13	8	24	71	26.42	20.75-34.00
June, 1955	13	6	24	119	27.60	20.25-37.75
July, 1955	10	7	18	89	25.97	20.50-36.50
August, 1955	15	9	24	109	25.23	20.00-36.50
September, 1955	14	8	23	89	26.14	20.25-41.00
October, 1954 and 1955	17	13	34	187	22.36†	15.00-35.50
November, 1954	9	6	17	97	21.55‡	13.50-40.00
Totals	121	77	214	1,004		

* These figures do not refer to the total number of salmon captured; therefore, they cannot be used to calculate the catch per unit of effort.
† Based upon fork lengths of 99 specimens.
‡ Based upon fork lengths of 60 specimens.

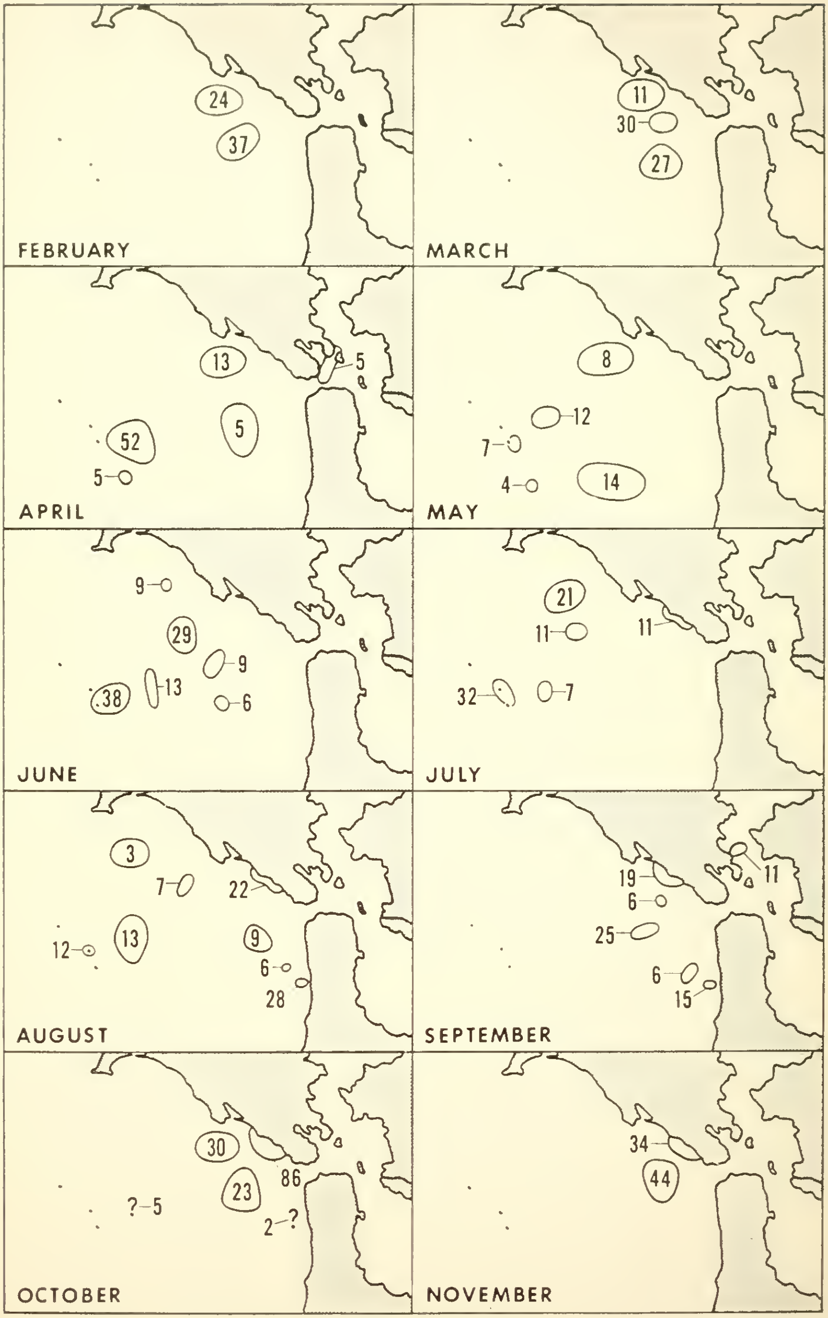

FIGURE 2. Areas in which the king salmon utilized in this study were captured, by months. Encircled areas show approximate locations of catches; figures state numbers of salmon stomachs examined from each area.

FINDINGS

Table 2 summarizes the monthly diets and the total diet of the king salmon utilized in this study. Figure 2 pictures the areas in which these king salmon were captured, by months. Figure 3 graphically shows the percentage composition, by volume, of the whole diet. Figure 4 illustrates the monthly variation in food habits.

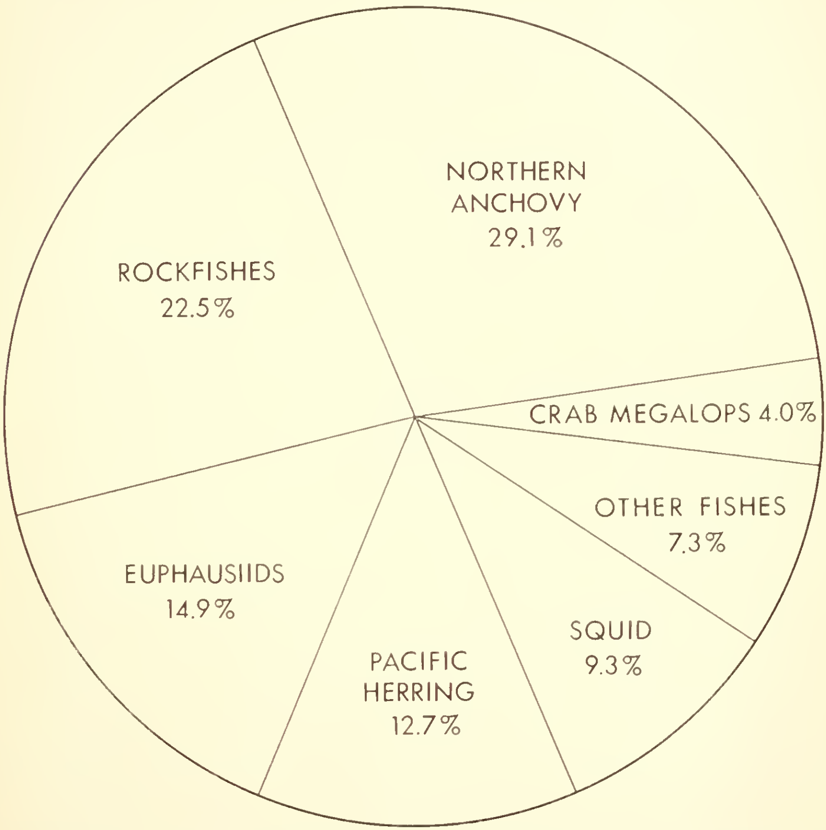

FIGURE 3. Percentage composition, by volume, of the food of 1,004 king salmon from the vicinity of San Francisco.

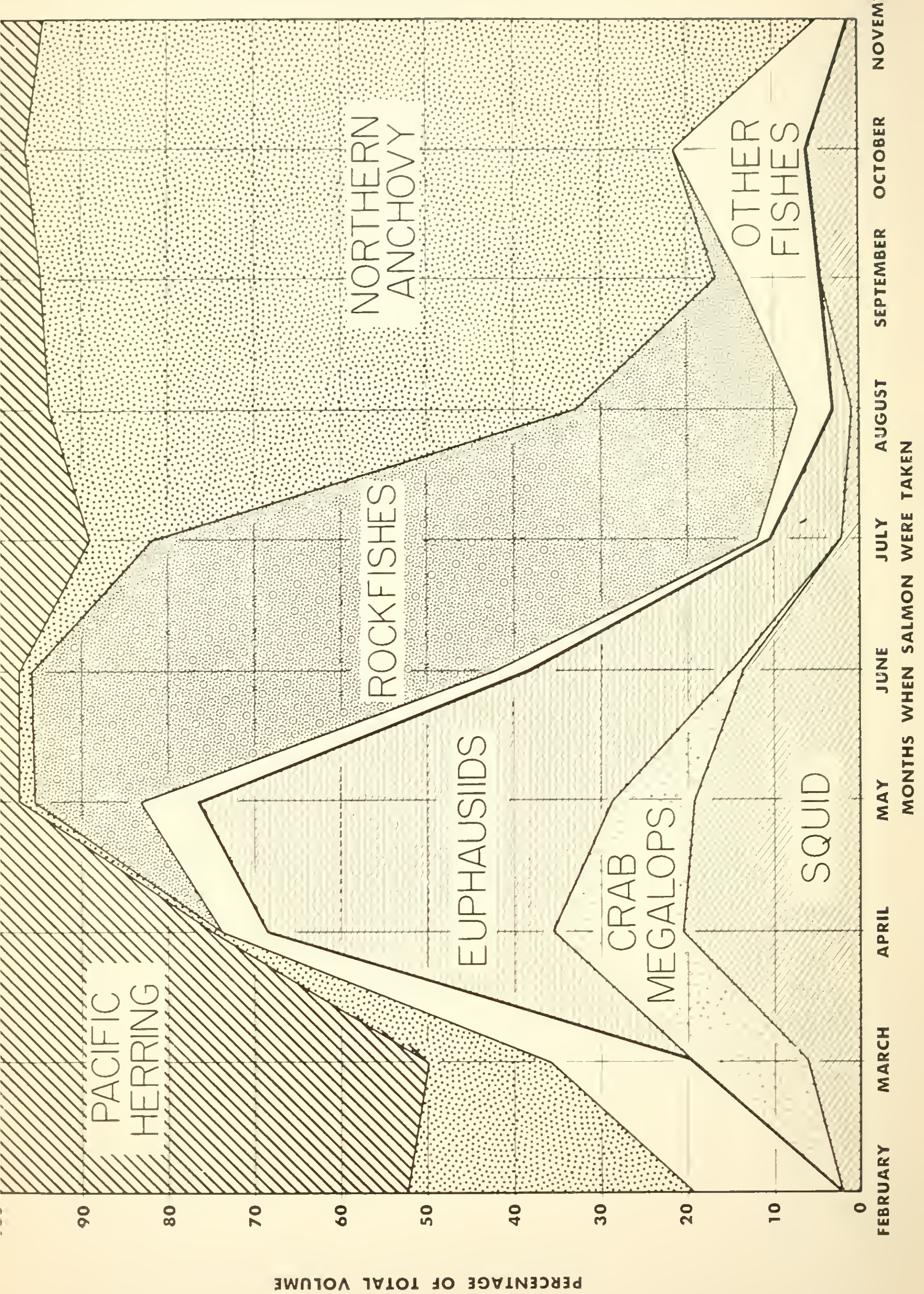
PACIFIC HERRING
NORTHERN ANCHOVY
ROCKFISHES
EUPHAUSIIDS
CRAB MEGALOPS
SQUID
OTHER FISHES
PERCENTAGE OF TOTAL VOLUME
0
10
20
30
40
50
60
70
80
90
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
MONTHS WHEN SALMON WERE TAKEN

TABLE 2

Percentage Composition, by Volume, of the Food of King Salmon From the Vicinity of San Francisco, According to the Month of Capture

Food item	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Total	Number stomachs in which occurred	Percentage frequency of occurrence	Total number of individuals	Size range (inches)
Pacific herring (*Clupea pallasi*)	17.4	51.2	25.9	2.9	3.1	11.2	6.5	5.5	3.7	5.9	12.7	91	9.1	115	3.0-10.0
Unidentified clupeids	1.5	0.3	0.1		0.1		0.7	0.7	0.7		0.3	17	1.7	20	--
Northern anchovy (*Engraulis mordax*)	32.9	13.1	0.5	1.6	1.2	7.1	60.1	77.9	71.7	89.6	29.1	277	27.6	794	2.0- 6.5
Whitebait smelt (*Allosmerus elongatus*)	1.3		1.9					0.9		--	0.3	1	0.4	8	5.0- 5.5
Smelt (*Spirinchus* sp.)	--							2.3	0.1		0.1	5	0.5	8	2.5- 4.5
Surf smelt (*Hypomesus pretiosus*)	1.4	10.5							0.9	--	1.1	8	0.8	10	3.0- 7.5
Unidentified osmerids	0.3	0.1					0.1	3.0	0.1	0.1	0.2	7	0.7	19	--
Pacific saury (*Cololabis saira*)									1.0	0.1	0.2	7	0.7	10	--
Pacific tomcod (*Microgadus proximus*)	7.0	3.1					0.3	1.7	5.2	--	1.4	6	0.6	6	5.0- 9.0
Unidentified gadids		0.1					0.2		0.3	0.4	0.1	4	0.4	1	--
Sanddab (*Citharichthys* sp.)				0.6					--	--	0.1	4	0.4	10	1.0- 2.0
Unidentified flatfishes			Tr.	0.1		--		--	0.1		Tr.	4	0.4	7	1.0- 8.0
Unidentified atherinids									1.6		0.7	2	0.2	2	11.0-12.0
Shiner seaperch (*Cymatogaster aggregata*)			1.0				0.9		0.4		0.3	3	0.3	1	3.5- 4.5
Unidentified embiotocids		0.5				--					Tr.	1	0.1	1	
Rockfishes (*Sebastodes* spp.)			0.7	12.2	53.1	69.7	25.3	2.9			22.5	215	21.4	1,459	1.0- 7.5
Lingcod (*Ophiodon elongatus*)	--	0.1	0.6	2.3	1.0						0.5	18	1.8	31	2.5- 4.5
Cabezon (*Scorpaenichthys marmoratus*)			0.2	0.2	0.2						0.1	5	0.5	5	2.0- 3.0
Irishlord (*Hemilepidotus* sp.)			0.2	0.5	Tr.						0.1	22	2.2	29	1.0- 1.5
Unidentified cottids			0.1	0.1	0.1						0.1	12	1.2	32	
Unidentified fish remains	2.8	1.2	0.2	2.7	2.3	1.4	2.1	0.8	2.0	2.0	1.7	222	22.1	353	
Polychaetes			0.1								Tr.	3	0.3		
Mysids			Tr.								Tr.	1	0.1	3	0.8
Euphausiids		Tr.	33.0	47.7	23.9	8.4	2.1				11.9	137	13.6	+24,000	0.4- 1.2
Prawn (*Pandalus* sp.)	0.4										Tr.	1	0.1	1	5.0
Shrimp (*Crago franciscorum*)									0.2		Tr.	2	0.2	2	3.0
Ghost shrimp (*Callianassa* sp.)				--					Tr.		Tr.	1	0.1	1	1.5
Crab megalops		13.3	15.0	9.5	1.0	Tr.					4.0	107	10.7	+10,800	0.3- 0.5
Adult crab			Tr.								Tr.	1	0.1	1	
Unidentified crustacean remains		Tr.	0.2	0.1							Tr.	11	1.1	--	--

TABLE 2—Continued

Percentage Composition, by Volume, of the Food of King Salmon From the Vicinity of San Francisco, According to the Month of Capture

Food item	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Total	Number stomachs in which occurred	Percentage frequency of occurrence	Total number of individuals	Size range inches
Octopus	--	--	--	0.2	0.2	0.2	0.7	--	--	--	0.1	7	0.7	8	0.1- 2.0
Squid	2.0	6.0	20.3	19.1	13.5	2.0	0.7	1.2	5.9	1.9	9.3	66	6.6	86	1.0- 6.0
Unidentified cephalopod remains	--	--	--	--	Tr.	Tr.	--	--	--	--	Tr.	2	0.2	2	-
Totals	100.0	100.1	100.0	100.1	100.0	100.0	100.0	99.9	99.9	100.0	99.9	--	--	--	--
Total volume of food in cubic centimeters	486.6	1,095.4	1,974.2	1,343.8	3,138.9	1,582.1	1,378.9	744.7	2,270.3	798.6	14,813.5	--	--		--
Number of stomachs with food	40	57	87	69	116	80	88	60	137	76	810	--			--
Number of empty stomachs	21	32	6	2	3	9	21	29	50	21	194		--		--
Percentage of empty stomachs	34.4	36.0	6.5	2.8	2.5	10.1	19.3	32.6	26.7	21.6	19.3	--	--		--

Troll-caught king salmon from the vicinity of San Francisco were found to have eaten a variety of fishes and invertebrates. However, six items—Pacific herring (*Clupea pallasi*), northern anchovy (*Engraulis mordax*), rockfishes (*Sebastodes* spp.), euphausiids, crab megalops, and squid—accounted for 92.5 percent of the total volume of food consumed.

There were marked seasonal changes in the composition of the food, with fishes forming the bulk of the diet during all of the months covered by this investigation except April and May, when invertebrates predominated. This is somewhat similar to the findings of Silliman (1941), who observed two distinct feeding phases for king and silver salmon—a fish-eating phase and an invertebrate-eating phase.

No single item of food was of major importance in all the monthly samples. During February and March the most important item in the diet was the Pacific herring. In April and May euphausiids had be-

TABLE 3

Percentage Composition, by Volume, of the Food of King Salmon Taken During March and April, According to Locality of Capture

Food item	Duxbury Point-San Francisco Lightship region		Near Farallon Islands	San Francisco Bay
	March	April	April	April
Pacific herring (*Clupea pallasi*)	57.2	8.9	32.6	--
Unidentified clupeids	1.0	--	0.1	--
Northern anchovy (*Engraulis mordax*)	19.0	--	--	33.4
Whitebait smelt (*Allosmerus elongatus*)	--	13.9	--	--
Surfsmelt (*Hypomesus pretiosus*)	6.8	--	--	--
Unidentified osmerids	0.1	--	--	--
Pacific tomcod (*Microgadus proximus*)	3.5	--	--	--
Shiner seaperch (*Cymatogaster aggregata*)	--	--	--	65.2
Unidentified embiotocids	0.5	--	--	--
Rockfishes (*Sebastodes* spp.)	--	--	0.7	--
Lingcod (*Ophiodon elongatus*)	0.1	0.4	0.7	--
Cabezon (*Scorpaenichthys marmoratus*)	--	--	0.2	--
Irishlord (*Hemilepidotus* sp.)	--	--	0.2	--
Unidentified cottids	--	--	0.1	--
Unidentified fish remains	1.5	Tr.	0.3	0.7
Polychaetes	--	0.8	--	--
Mysids	--	Tr.	--	--
Euphausiids	--	Tr.	38.9	--
Crab megalops	10.3	76.0	3.0	Tr.
Adult crab	--	--	--	0.7
Unidentified crustacean remains	--	Tr.	0.2	--
Squid	--	--	23.0	--
Totals	100.0	100.0	100.0	100.0
Total volume of food in cubic centimeters	1,056.8	274.1	1,491.1	29.9
Number of stomachs	68	18	57	5

come the main food, only to be replaced by rockfishes in June and July. From August to November northern anchovies made up the bulk of the diet.

Seasonal changes in food habits were, to some extent, related to shifts in the locality of capture. During February and March, when the main food was Pacific herring, all of the salmon whose locality of capture was known were caught in the Duxbury Point-San Francisco Lightship region, largely between the 10- and 20-fathom curves. In April and May, when the dominant food was euphausiids, the majority of the salmon were captured near the Farallon Islands and in other waters outside the 20-fathom curve. However, some of the April specimens were from the Duxbury Point-San Francisco Lightship region and from San Francisco Bay. When the food habits of salmon taken in the different areas during April were compared with each other and with the food habits of salmon known to have been captured in the Duxbury Point-San Francisco Lightship region during March (Table 3), the data showed that euphausiids were important only in the diet of specimens taken near the Farallon Islands during April. This is believed to indicate that the change from Pacific herring to euphausiids as the main item of food was related to the shift in the area of capture. On the other hand, the great difference between the March and April diets of salmon taken in the Duxbury Point-San Francisco Lightship region indicates a change in food habits without a major shift in the locality of capture.

The change from a diet in which the main food was rockfishes to one dominated by northern anchovies also appears to be related to a shift in the locality of capture. During June and July, when rockfishes predominated in the diet, most of the salmon were still taken near the Farallon Islands and in other areas outside the 20-fathom curve. From August to November, when the bulk of the diet consisted of northern anchovies, the majority of the salmon were caught inside the 20-fathom curve. A few of the specimens in the July sample came from inside the 20-fathom curve, just as some of those in the August sample were from outside the 20-fathom curve. The food habits of both the July and August specimens were compared according to area of capture (Table 4). The data showed that during both July and August the northern anchovy was the chief food of salmon taken inside the 20-fathom curve, whereas rockfishes predominated in the diet of salmon from outside the 20-fathom curve.

Northern Anchovy

Seven hundred and ninety-four northern anchovy (*Engraulis mordax*), appearing in 27.6 percent of the stomachs examined, constituted 29.1 percent of the total volume of food consumed. This was the most important item in terms of volume and frequency of occurrence. Both young and adult anchovies were eaten; they ranged in length from 2.0 to 6.5 inches.

Northern anchovies were utilized as food for the salmon during all 10 months in which stomachs were collected. Consumption was heaviest in the late summer and fall months, when most of the salmon were caught inside the 20-fathom curve. This item accounted for 60.4 percent of the August diet, 77.9 percent of the September diet, 74.7 percent of

TABLE 4

Percentage Composition, by Volume, of the Food of King Salmon Taken During July and August, According to Locality of Capture

Food item	Outside 20-fathom curve		Inside 20-fathom curve	
	July	August*	July	August
Pacific herring (*Clupea pallasi*)	11.5	12.1	7.7	4.2
Unidentified clupeids	--	--	--	1.2
Northern anchovy (*Engraulis mordax*)	1.5	4.5	92.3	90.7
Pacific tomcod (*Microgadus proximus*)	--	--	--	0.4
Unidentified gadids	--	--	--	0.3
Shiner seaperch (*Cymatogaster aggregata*)	--	--	--	1.5
Rockfishes (*Sebastodes* spp.)	74.2	71.1	--	0.4
Unidentified fish remains	1.5	1.4	--	1.4
Euphausiids	8.9	6.6		
Crab megalops	Tr.		--	--
Octopus	0.2	2.3	--	--
Squid	2.1	2.0		--
Unidentified cephalod remains	Tr.	--		
Totals	99.9	100.0	100.0	100.1
Total volume of food in cubic centimeters	1,376.1	443.3	97.5	848.3
Number of stomachs	71	28	11	65

* Omitted were seven specimens taken almost on the 20-fathom curve.

the October diet, and 89.6 percent of the November diet. Northern anchovies were of some importance in February and March, when most of the salmon came from the Duxbury Point-San Francisco Lightship region. During the spring months, however, when the salmon were taken chiefly beyond the 20-fathom curve, northern anchovies were seldom encountered in the diet. This was the only item identified from the stomachs of the salmon captured in San Francisco Bay during September, and the only item to occur more than once in the stomachs of salmon taken in the Bay during April.

Rockfishes

One thousand, four hundred and fifty-nine rockfishes (*Sebastodes* spp.) were found in 21.4 percent of the stomachs and comprised 22.5 percent of the total bulk. This item was second in importance from the standpoints of volume and percentage of salmon stomachs containing them. All of the rockfishes taken were small, varying between 1.0 and 7.5 inches in length. Few specimens exceeded a length of 3.5 inches. Among 519 undigested or slightly digested specimens sent to Mr. Phillips for identification, 19 species were represented (Table 5).

More than two-thirds of the rockfishes identified were shortbelly rockfish (*Sebastodes jordani*). This species attains a maximum total length of approximately 12 inches, and is of no commercial value. According to Mr. Julius B. Phillips (personal communication), it appears to be an important forage fish, for it occurs in great numbers off the California coast and is commonly eaten by a number of other

TABLE 5

List of Rockfishes (Sebastodes spp.) Identified

Species	Number of individuals
Shortbelly rockfish (*Sebastodes jordani*)	362
Speckled rockfish (*Sebastodes ovalis*)	23
Yellowtail rockfish (*Sebastodes flavidus*)	19
Widow rockfish (*Sebastodes entomelas*)	13
Whitebelly rockfish (*Sebastodes vexillaris*) or copper rockfish (*S. caurinus*)	8
Squarespot rockfish (*Sebastodes hopkinsi*)	7
Dark-blotched rockfish (*Sebastodes crameri*)	6
Aurora rockfish (*Sebastodes aurora*)	4
Black rockfish (*Sebastodes melanops*)	4
Stripetail rockfish (*Sebastodes saxicola*)	3
Bocaccio (*Sebastodes paucispinis*)	2
Redstripe rockfish (*Sebastodes proriger*)	2
Rosy rockfish (*Sebastodes rosaceus*)	2
Sharpchin rockfish (*Sebastodes zacentrus*)	2
Brown rockfish (*Sebastodes auriculatus*)	2
Chilipepper (*Sebastodes goodei*)	1
Canary rockfish (*Sebastodes pinniger*)	1
Turkey-red rockfish (*Sebastodes ruberrimus*)	1
Greenstriped rockfish (*Sebastodes elongatus*)	1
Rockfishes (unidentifiable)	56
Total number of specimens	519

species, including the larger rockfishes. Most of the shortbelly rockfish consumed by the king salmon were from 3.0 to 3.5 inches in length.

Despite their importance in the total diet, rockfishes appeared in only six of the 10 monthly samples. Consumption of this item gradually increased from 0.7 percent in April to 69.7 percent in July, and then declined to 2.9 percent in September. Although rockfishes were found mainly in the stomachs of salmon captured beyond the 20-fathom curve, a few had been eaten by salmon taken inside the 20-fathom curve and even inside the 10-fathom curve.

Euphausiids

These small shrimp-like creatures appeared in 13.6 percent of the stomachs and amounted to 14.9 percent of the total volume. Over 24,000 euphausiids were found, more than all the other food organisms combined. Samples of euphausiids from 120 king salmon were identified. Only two species were present—*Thysanöessa spinifera*, which was represented in 118 of the samples, and *Euphausia pacifica*, which occurred in 13. One stomach was found with immature *Thysanöessa spinifera* in it; the rest contained only adults.

According to Mr. Edward Brinton (personal communication), great shoals of *Thysanöessa spinifera* have been seen at the surface of the water near the islands off southern California, and presumably may be found in more northern waters also. He added that this seems to be the only species occurring in Californian waters which is conspicuous by its faculty for swarming and shoaling. Regarding *Euphausia pacifica*, Mr. Brinton stated that its heaviest concentrations occur farther offshore than the continental shelf region in which *Thysanöessa spinifera* predominates.

The .e small crustaceans, which averaged about one inch in length, were often consumed in great numbers. More than one-quarter of the 137 stomachs with euphausiids in them contained from 200 to 1,000 individuals, and over 1,500 (170 cc.) were found in the stomach of a salmon 27.5 inches long.

Euphausiids were taken exclusively from March to August. Consumption was negligible in March, but increased to 33.0 percent and 47.7 percent, respectively, in April and May. They then gradually diminished in importance until only 2.1 percent of the August diet consisted of this item. Although a few euphausiids were found in the stomachs of salmon taken just inside the 20-fathom curve, the great majority of these organisms had been eaten by salmon which were captured beyond the 20-fathom curve.

Pacific Herring

One hundred and fifteen Pacific herring (*Clupea pallasi*), appearing in 9.1 percent of the stomachs, made up 12.7 percent of the total food consumption. This was the largest item commonly eaten by the salmon. The specimens consumed ranged in length from 3.0 to 10.0 inches. However, the majority were between 7.0 and 9.0 inches. Although usually there was only one large herring per stomach, on two occasions four of these fish were found in the stomachs of large salmon.

Pacific herring entered the diet in all 10 months covered by this study. They appeared in the stomachs of salmon taken at widely scattered points, from the Farallon Islands to one-quarter of a mile off the coast. This item was most heavily utilized during the months of February (47.4 percent), March (51.2 percent), and April (25.9 percent). The large herring were represented in all the monthly samples, but those 5.0 inches or less were taken only in the late summer and fall months.

Squid

Eighty-six squid accounted for 9.3 percent of the entire diet, and 6.6 percent of the stomachs were found to contain this item of food. Most of these squid were between 3.0 and 6.0 inches in body length, but a few were smaller. Only one species, *Loligo opalescens*, was identified. However, many partly digested specimens, which could not be specifically identified, were encountered.

This item was observed in all of the monthly samples, although it was never of primary importance. Squid were taken most frequently during the spring months, forming 20.3 percent of the April food, 19.1 percent of the May food, and 13.5 percent of the June food. While squid occurred in the stomachs of salmon captured inside the 20- and even the 10-fathom curves, the majority had been eaten by salmon taken beyond the 20-fathom curve.

Crab Megalops

More than 10,800 crab megalops occurred in 10.7 percent of the stomachs and comprised 4.0 percent of the total bulk. This was the smallest item frequently taken by the salmon. Crab megalops were not consumed in such great numbers as were euphausiids. Rarely were there more than 500 individuals per stomach.

Lack of descriptions of the megalops stages of the different crabs occurring in California waters made it impossible to specifically identify the specimens found in the stomachs. The relatively large size (average length about 0.3 inches) and general appearance seemed to indicate that the species was *Cancer magister*, one of the commonest forms in the study area. However, more than one species may have been eaten.

Crab megalops were taken only from March to July, and consumption of this item was greatest in March (13.3 percent), April (15.0 percent), and May (9.5 percent). They were consumed by salmon captured inside and outside the 20-fathom curve.

Other Fishes

Seven and three-tenths percent of the total food volume was made up of fishes other than those already mentioned.

Twenty unidentified clupeids occurred in a total of 17 stomachs. Many, if not all, of these were doubtless Pacific herring, since no intact specimen of any other clupeid was found.

In all, 45 smelt (family Osmeridae) appeared in 24 stomachs. Three forms were identified—*Allosmerus elongatus*, *Spirinchus* sp., and *Hypomesus pretiosus*. Young and adults, ranging from 2.5 to 7.5 inches in length, were eaten. Smelts of one species or another were encountered in all the monthly samples except those of May, June, and July, but were not found in the stomachs of salmon known to have been captured outside the 20-fathom curve. Consumption was heaviest in March, when 10.6 percent of the diet consisted of this kind of food.

Seven stomachs, collected during October and November, contained the remains of 10 Pacific saury (*Cololabis saira*). It may be significant that the only food present in the stomachs of the five salmon captured well outside the 20-fathom curve during October was one Pacific saury.

Gadids, including the Pacific tomcod (*Microgadus proximus*), occurred 10 times, only one per stomach, during February and March and from August to November. They were found solely in the stomachs of salmon captured inside the 20-fathom curve.

A total of 16 young sanddabs (*Citharichthys* sp.) and young unidentified flatfishes were eaten by seven salmon captured outside the 20-fathom curve during April and May. The remains of one unidentified flatfish, estimated to be about eight inches long, were found in the October sample.

During October two stomachs each were found to contain an atherinid, which was probably a jacksmelt (*Atherinopsis californiensis*). These were the largest food organisms seen (11.0 and 12.0 inches long), and because of their size they accounted for 4.6 percent of the October material.

A total of five embiotocids, including shiner seaperch (*Cymatogaster aggregata*), appeared in the March, April, August, and October diets. All were found in the stomachs of salmon caught inside the 20-fathom curve. One of the shiner seaperch was eaten by a salmon taken in San Francisco Bay.

Young lingcod (*Ophiodon elongatus*), 34 specimens in all, were present in 18 stomachs collected from March to June. They were all quite

small in size (2.5 to 4.5 inches long). This item was most important in May, when it made up 2.3 percent of the diet of that month. Almost all the lingcod appeared in the stomachs of salmon from beyond the 20-fathom curve.

Young sculpins (family Cottidae) were represented in the diet by at least two species—cabezon (*Scorpaenichthys marmoratus*) and Irish-lord (*Hemilepidotus* sp.). The former ranged in length from 2.0 to 3.0 inches, and the latter were from 1.0 to 1.5 inches long. Thirty-four salmon containing 66 sculpins were taken outside the 20-fathom curve during April, May, and June.

Other Invertebrates

Although a variety of other invertebrates was encountered, only 0.1 percent of the total bulk consisted of items in this category.

Remains of polychaetes were found in three stomachs collected during April. Some were identified as heteronereids, which are the free-swimming sexual stages of otherwise benthic polychaetes.

Three mysids were found in the stomach of a salmon captured during April.

Adult decapod crustaceans were eaten occasionally. One prawn (*Pandalus* sp.) was taken in February. Two shrimp (*Crago franciscorum*) and one ghost shrimp (*Callianassa* sp.) appeared in the October diet. The remains of one adult crab were found in the stomach of a salmon captured in San Francisco Bay during April.

Unidentified crustacean remains were found only in March, April, and May. These remains may have been composed largely of euphausiids and crab megalops, since these organisms were most heavily utilized at that time of year.

Small octopi were represented seven times from May to August in the stomachs of salmon captured outside the 20-fathom curve.

Differences in Food Habits According to Size

Chapman (1936) compared the stomach contents of three size groups of king salmon examined at Neah Bay, Washington. He found that the smallest sizes, 11 to 20 inches in length, contained no sardines or herring, but lived almost entirely on euphausiids. Those intermediate in size, 21 to 30 inches in length, still ate euphausiids but also took sardines and herring, in the ratio of two grams of the former to one of the latter. The largest sizes, 31 to 50 inches in length, subsisted mainly on fish, taking about three grams of sardines to one of herring to 0.3 of euphausiids.

Milne (1955) found that one-half of the stomachs of king salmon over 26 inches in total length contained herring, whereas only one-fifth of the stomachs of smaller specimens had this type of food. (These herrings ranged from 5.9 to 7.5 inches in standard length.)

In the present study the food habits of the large and small salmon were found to be generally similar, even in February and March, when large Pacific herring formed a substantial part of the diet. Frequently salmon less than 22 inches in fork length had taken large herring. In one instance the stomach of a 19-inch salmon contained a herring no less than eight inches long, and there were other cases of salmon having swallowed food fishes more than one-third their own length. Only among

TABLE 6

Percentage Composition, by Volume, and Percentage Frequency of Occurrence of the Food Items Consumed by Different Sizes of Salmon Captured Near the Farallon Islands During April

Food item	Less than 25 inches (fork length)		25 inches or more (fork length)	
	Volume	Frequency	Volume	Frequency
Pacific herring (*Clupea pallasi*)	11.8	12.5	45.6	24.2
Unidentified clupeids			0.2	3.0
Rockfishes (*Sebastodes* spp.)	0.8	20.8	0.7	15.2
Lingcod (*Ophiodon elongatus*)	1.1	4.2	0.4	3.0
Cabezon (*Scorpaenichthys marmoratus*)			0.3	3.0
Irishlord (*Hemilepidotus* sp.)	0.2	12.5	0.2	15.2
Unidentified cottids	0.1	4.2	0.2	6.1
Unidentified fish remains	0.2	16.7	0.3	24.2
Euphausiids	53.8	62.5	29.6	69.7
Crab megalops	1.2	25.0	4.1	15.2
Unidentified crustacean remains	0.5	4.2	0.1	3.0
Squid	30.4	29.2	18.4	18.2
Totals	100.1	--	100.1	----
Total volume of food in cubic centimeters	576.5		914.6	
Number of stomachs	24		33	

the salmon captured near the Farallon Islands during April was a marked difference in the food habits of large and small salmon noted. These salmon were arbitrarily separated into two size groups—those less than 25 inches in fork length and those 25 or more inches in fork length—and their food habits compared (Table 6). Although euphausiids appeared in roughly the same percentage of stomachs in both size groups (62.5 percent of the small salmon; 69.7 percent of the large salmon), they formed 53.8 percent of the food consumption of the former group and 29.6 percent of the food consumption of the latter group. Pacific herring comprised 11.8 percent and 45.6 percent, respectively, of the food of the small and large salmon.

Differences in the Amounts of Food Eaten

Silliman (1941) noted a positive correlation between the troll catch of king and silver salmon and the quantity of fish found in their stomachs. However, in the case of silver salmon captured during October and November he observed an exception, which he attributed to the approaching sexual maturity of this species. Of this he had the following to say:

In seeming contradiction to the correlation, a large catch of silver salmon was taken in October and November, when the fish content of stomachs was small. This may have resulted from a condition not present during the other months of the study, namely, the sexual maturity of the silver salmon. The species is a "fall spawner" . . . and the fishing in October and November is largely upon schools starting their spawning migration to the streams and rivers. Since the silver salmon spawn closer to the mouths of the streams and rivers than the chinooks the gonads of members of the former species preparing to make the upstream migration must be further developed than those of the latter.

Now it is known that spawning fish do not feed normally after they have entered fresh water. That this influence extends also to fish nearing sexual maturity that are still in the sea, seems to be borne out by the extremely small amounts of food of any kind found in the stomachs of silver salmon collected in October and No-

vember . . . Nevertheless, the fish still strike at fishermen's lures, as evidenced by the large catch. There apparently persists in the ripe fish a reflex which causes them to strike at objects resembling fish, even though they do not swallow them . . .

In view of Silliman's observations on silver salmon, an attempt was made to determine whether the king salmon utilized in the present study showed any indication that they had ceased to feed, or at least had taken less food, prior to entering fresh water to spawn.

According to Fry and Hughes (1951), most of the salmon tagged off central California turned out to be from the Sacramento-San Joaquin River system. The California Department of Fish and Game statistical reports show that the heaviest commercial salmon catches in the Sacramento-San Joaquin River system are made during the month of September. Therefore, it would seem likely that if the salmon cease to feed prior to entering fresh water to spawn, those in the vicinity of San Francisco would do so during September.

A comparison of the percentage of empty stomachs occurring in each monthly sample (Table 2) revealed that while a large portion of the stomachs of salmon taken in September were empty, even larger percentages of specimens captured in February and March had no food in their stomachs. However, when the quantity of food per unit of body weight was calculated for each monthly sample (Table 7), the data revealed that during September there were fewer cubic centimeters of food per pound of salmon than in any other month.

The September specimens were then grouped according to their degree of sexual maturity. By plotting the fork lengths of the salmon against the weights of their preserved gonads it was possible to distinguish salmon about to spawn that fall from those not ready to spawn for at least another year, because of the enormous development of the gonads of the salmon in the former group. (Specimens with gonads intermediate in size were disregarded.) Among the individuals with large gonads a distinction was made as to whether they had been caught in

TABLE 7

Cubic Centimeters of Food per Pound of Salmon, Acording to Month

Month	Number of specimens	Total volume of food consumed (in cc.)	Average volume of food per stomach (in cc.)	Average weight salmon of (in pounds)*	Cc. of food per pound of salmon†
February	61	486.6	8.0	4.5	1.8
March	89	1,095.4	12.3	5.3	2.3
April	93	1,974.2	21.2	7.0	3.0
May	71	1,343.8	18.9	9.0	2.1
June	119	3,138.9	26.4	9.9	2.7
July	89	1,582.1	17.8	8.2	2.2
August	109	1,378.9	12.7	7.5	1.7
September	89	744.7	8.4	8.3	1.0
October	187	2,270.3	12.1	5.3	2.3
November	97	798.6	8.2	4.5	1.8

* To obtain these figures the average fork lengths, as given in Table 1, column 6, were first converted to average dressed weights, by the use of Fry and Hughes' (1951) length-weight relationship. The true average weights were then determined by adding 12.8 percent to the average dressed weight in accordance with the findings of Fry (1952) concerning cleaning losses in king salmon.

† These figures were calculated by dividing the average volume of food per stomach by the corresponding average weight of the salmon.

TABLE 8

Cubic Centimeters of Food per Pound of Salmon According to Stage of Maturity

(All of these salmon were taken during September)

Stage of maturity	Number of specimens	Total volume of food consumed (in cc.)	Average volume of food per stomach (in cc.)	Average weight of salmon (in pounds)*	Cc. of food per pound of salmon		
					Mean†	Standard error of the mean	95% confidence interval
Not about to spawn, ocean-caught	12	61.5	5.1	7.0	0.78	0.33	0.12-1.44
About to spawn, ocean-caught	50	602.3	12.0	7.9	1.91	0.36	1.19-2.63
About to spawn, bay-caught	11	3.3	0.3	11.6	0.04	0.03	0.00-0.10

* Average weights were obtained from average fork lengths by the same method described in footnote 1 to Table 7.
† The cubic centimeters of food per pound of salmon was calculated for each specimen and then those in each group were averaged.

the ocean or in San Francisco Bay, the latter being regarded as further along in their sexual development, inasmuch as they had already left the ocean and presumably were on their way to the spawning beds in the Sacramento-San Joaquin River system, which empties into San Francisco Bay. (No specimens with undeveloped gonads were taken in the Bay during September.) The quantity of food per unit of body weight was computed for each of these three groups of salmon (Table 8). The lowest figure was obtained for maturing salmon captured in San Francisco Bay and the highest figure for maturing salmon taken in the ocean. It seems that the king salmon which were taken in San Francisco Bay and which presumably were moving into the Sacramento-San Joaquin River system to spawn had almost ceased feeding, whereas the ocean-caught salmon which were about to spawn had not.

SUMMARY

1. The stomach contents of 1,004 troll-caught king salmon from the vicinity of San Francisco were analyzed.
2. Six items constituted 92.5 percent of the total food consumption. These items were northern anchovy (29.1 percent), rockfishes (22.5 percent), euphausiids (14.9 percent), Pacific herring (12.7 percent), squid (9.3 percent), and crab megalops (4.0 percent).
3. The composition of the food changed seasonally. The dominant food in February and March was the Pacific herring; in April and May, euphausiids; in June and July, rockfishes; and from August to November, northern anchovy.
4. Seasonal changes in food habits were, in some cases, related to shifts in the locality of capture.
5. The food habits of the different sizes of king salmon utilized in this study were found to be generally similar. King salmon were observed to feed on fishes more than one-third their own length.
6. Maturing king salmon taken in San Francisco Bay during September apparently had almost ceased feeding. There was no evidence to indicate that ocean-caught salmon approaching sexual maturity had ceased to feed.

REFERENCES

California, Commissioners of Fisheries
1877. Salmon (*Salmo quinnat*). *In:* Report of the Commissioners of Fisheries of the State of California for the years 1876 and 1877. p. 5-22.

Chapman, Wilbert McLeod
1936. The pilchard fishery of the state of Washington in 1936 with notes on the food of the silver and chinook salmon off the Washington coast. Wash. Dept. Fish., Biol. Rept. no. 36C, 30 p.

Clothier, Charles
1950. A key to some southern California fishes based on vertebral characters. Calif. Div. Fish and Game, Fish Bull. 79, 83 p.

Foskett, D. R.
1951. Young salmon in the Nanaimo area. Fish. Res. Bd. Canada, Pac. Coast Sta., Prog. Rept. 86, p. 18-19.

Fraser, C. McLean
1946. Food of fishes. Roy. Soc. Canada, Trans., ser. 3, vol. 40, sect. 5, p. 33-39.

Fry, Donald H., Jr.
1952. Cleaning losses in king and silver salmon. Calif. Fish and Game, vol. 38, no. 3, p. 425-426.

Fry, Donald H., Jr., and Eldon P. Hughes
1951. The California salmon troll fishery. Pac. Mar. Fish. Comm., Bull. 2, p. 7-42.

Gilbert, Charles H.
1913. The salmon of Swiftsure Bank. Brit. Columbia, Comm. Fish., Rept. for 1912, p. 1 14-1 18.

Heg, Robert, and Jack Van Hyning
1951. Food of the chinook and silver salmon taken off the Oregon coast. Oregon Fish Comm. Res. Briefs, vol. 3, no. 2, p. 32-40.

Martin, A. C., R. H. Gensch, and C. P. Brown
1946. Alternative methods in upland gamebird food analysis. Jour. Wildl. Mangt., vol. 10, no. 1, p. 8-12.

Milne, D. J.
1955. Selectivity of trolling lures. Fish. Res. Bd. Canada, Pac. Coast Sta., Prog. Rept. 103, p. 3-5.

Pritchard, A. L., and Albert L. Tester
1944. Food of spring and coho salmon in British Columbia. Fish. Res. Bd. Canada, Bull., 65, 23 p.

Roedel, Phil M.
1953. Common ocean fishes of the California coast. Calif. Dept. Fish and Game, Fish Bull. 91, 184 p.

Senter, Vance E.
1940. Observations on the food of Pacific salmon. Pac. Fisherman, vol. 38, no. 4, p. 26.

Silliman, Ralph P.
1941. Fluctuations in the diet of the chinook and silver salmons (*Oncorhynchus tschawytscha* and *O. kisutch*) off Washington, as related to the troll catch of salmon. Copeia, no. 2, p. 80-87.

Snyder, J. O.
1924. Young salmon taken at sea. Calif. Fish and Game, vol. 10, no. 2, p. 62-64.

Whitney J. Parker
1893. Salmon in salt water. Forest and Stream, vol. 41, no. 6, p. 120-121.

THE USE OF WIRE FYKE TRAPS TO ESTIMATE THE RUNS OF ADULT SALMON AND STEELHEAD IN THE SACRAMENTO RIVER[1]

RICHARD J. HALLOCK
Inland Fisheries Branch
California Department of Fish and Game

D. H. FRY, JR.
Marine Fisheries Branch
California Department of Fish and Game
and

DON A. LaFAUNCE
Inland Fisheries Branch
California Department of Fish and Game

TABLE OF CONTENTS

[1] Submitted for publication March, 1957. This was a cooperative project carried out with funds provided by the Marine Fisheries Branch and by Federal Aid in Wildlife Restoration Project California F-7-R, "Sacramento-San Joaquin River Salmon and Steelhead Study".

INTRODUCTION

One of the basic tools necessary for proper management of salmon and steelhead is a knowledge of the sizes of their annual spawning escapements or runs. Other information, including the time these runs enter different river systems, the spawning periods, and the areas in each stream utilized by the fish for spawning purposes is also essential to manage this resource effectively.

Such data are becoming increasingly valuable in planning for the safety and maintenance of salmon and steelhead runs, in view of the multitude of water development projects on our streams, both proposed and under construction.

Since 1939 the California Department of Fish and Game has made population estimates of fall-run king salmon *(Oncorhynchus tshawytscha)* in various Sacramento-San Joaquin Valley streams. Most of this work has been done by the Marine Fisheries Branch. Steelhead rainbow trout *(Salmo gairdneri gairdneri)* research in the Central Valley did not become a full time program until 1952 and has been conducted since then in the Sacramento River system by Dingell-Johnson Project F-7-R, "Sacramento-San Joaquin River Salmon and Steelhead Study", under the Inland Fisheries Branch.

Whenever possible, fish ladder counts have been used for salmon enumeration, but there are relatively few permanent weirs or dams in the Central Valley where complete, or even partial, counts can be made. Most of the diversion dams are upstream from the major spawning areas.

During the period from 1939 through 1942, when fish ladders were not available, the method used was to count salmon through an opening in a weir built across the stream. This method did not prove satisfactory, since the weirs washed out during high water.

In 1943, weir counts were abandoned by the Department, and a tag and recovery method was substituted. This method of population estimation requires only that a known number of salmon be tagged and allowed to proceed upstream to spawn and die. From the ratio of tagged to untagged carcasses on the spawning beds, it is possible to calculate the size of the spawning run.

The first method of capturing salmon for this tagging employed a temporary V-shaped webbing weir, which extended across the entire stream. The apex of the "V" was at the upstream end. An opening at the apex allowed the fish to enter a trap, where they remained until removed for tagging. This method proved satisfactory in use on the American and Stanislaus rivers.

In 1950 it was decided to do some experimental fishing in the Sacramento River to determine if it was practical to make a tag and recovery estimate of the fall salmon run. The Sacramento carries a considerable amount of traffic, including both commercial tugs and private vessels. It is also too large to permit use of a weir of the type just described. Obviously, another method of capturing fish had to be used. Gill nets were first selected, principally because we had had considerable experience in their use. The area fished was about one and one-half miles upstream from the mouth of the Feather River. Though showing promise, this method was abandoned as being impractical with the manpower available.

In 1951 the Department initiated the use of large wire-mesh traps. These cylindrical fish traps, 10 feet in diameter and $19\frac{1}{2}$ feet long, were patterned after traps formerly used by commercial fishermen in the Sacramento River near Princeton Ferry. Such traps had been declared illegal for commercial fishing several years previously. After considerable searching, an abandoned trap was found in a heavily wooded area adjacent to the Sacramento River between Princeton Ferry and Colusa. Measurements were taken of the abandoned trap and six new ones were constructed during the summer of 1951. These traps were first fished in the Sacramento River in the fall of 1951. They were quite successful in taking salmon, and much to everybody's surprise they also took large numbers of steelhead. At that time very little was known about the migration of steelhead into the upper Sacramento River. It was decided to take advantage of this unexpected opportunity and tag all trapped steelhead. The procedure for determining the sizes of runs for both salmon and steelhead, with the tag recovery method, is essentially the same. The principal difference is that steelhead do not die after spawning, so the ratio of tagged to untagged steelhead is determined by examining live fish.

Starting with the summer of 1953, seven traps have been operated co-operatively in the Sacramento River by Dingell-Johnson Project F-7-R and Marine Fisheries Branch personnel. Salmon data have been analyzed by Marine Fisheries Branch personnel and the Dingell-Johnson personnel have concentrated on the steelhead data.

This report is a summary of the present methods used in constructing the fish traps, their operation in the Sacramento River, and a generalized treatise on the effectiveness of these traps in capturing king salmon, steelhead trout, silver salmon (*Oncorhynchus kisutch*), striped bass (*Roccus saxatilis*), American shad (*Alosa sapidissima*), and other species of fishes.

ACKNOWLEDGMENTS

Success of the trapping program on the Sacramento River has been due to the efforts of many persons in the Department of Fish and Game. In addition, land owners in the trapping area have been most generous in permitting unrestricted use of their land to operate the traps, and from time to time have helped to clear brush and trees from net fishing sites.

We are especially indebted to the late Mr. David J. Glenn of the Department of Fish and Game. Mr. Glenn's knowledge of the Sacramento River, and of commercial fishing and fishing gear, gained through many years of commercial fishing experience on the river, coupled with an inherent drive to experiment with new ideas, contributed perhaps the most to the successful development and operation of these traps.

To Mr. Taylor London, warden with the Department of Fish and Game, we also wish to express our gratitude. It was largely through his efforts that one of the old abandoned commercial fish traps was located.

To them and many others we wish to express our heartiest thanks.

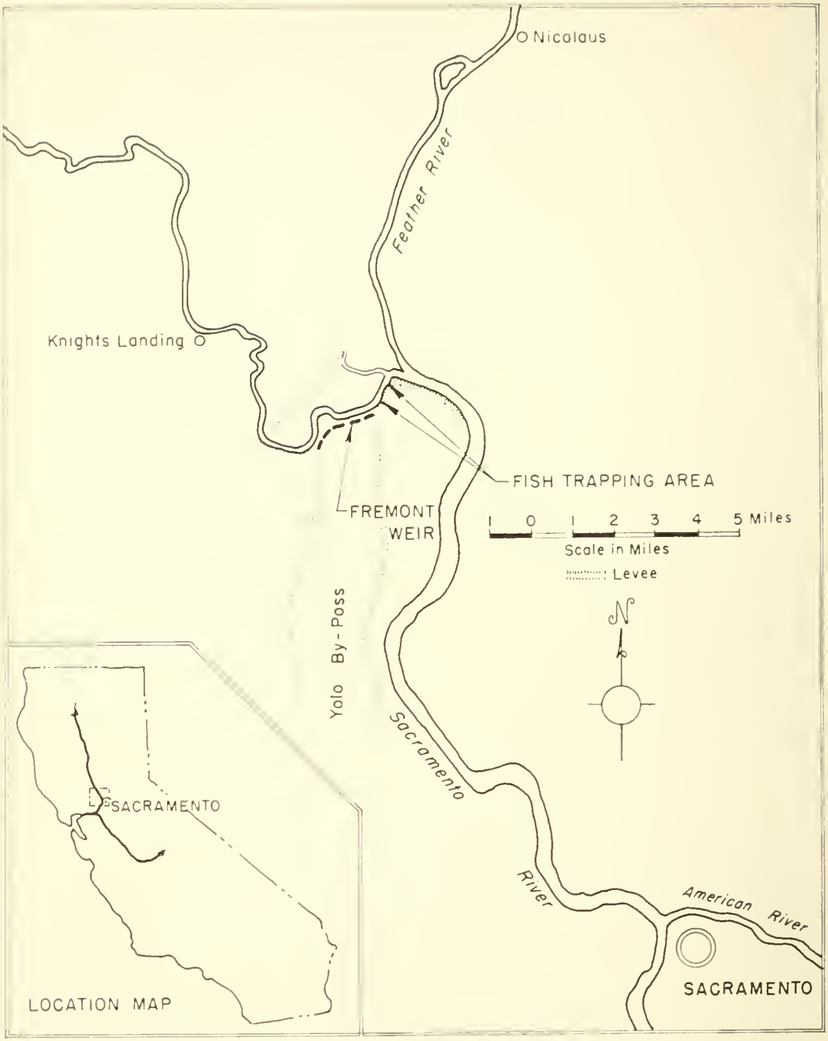

FIGURE 1. Map showing the trapping area and nearby points.

DESCRIPTION OF THE TRAPPING AREA

The trapping area starts at the downstream end of Fremont Weir and extends downstream along the right bank of the river for a distance of about one and one-half miles. The lower end is about one-half mile above the mouth of the Feather River. Fremont Weir is located 23 river miles upstream from the City of Sacramento. It is a flood control structure over which flood waters spill from the Sacramento River into the Yolo Bypass.

The Sacramento River near the trapping area is about 150 feet wide and of variable depth. In the main channel, depths of 30 and 40 feet are common. Along the steep dirt and sand banks characteristic of this section, water depths of 20 feet are common a few feet from shore, even during low summer and fall flows. The river drops one foot in elevation about every three miles. There are no gravel riffles. The first riffles of any consequence are found just above the City of Colusa, some 70 miles farther upstream. During summer and fall months the river flow in this area is usually between 5,000 and 10,000 cubic feet per second. Water velocities of 2 to 3 feet per second are encountered at the individual trapping sites, which are close to shore. Velocities in the center of the river are higher. Figure 2 shows a general view of the Sacramento River at the upper end of the trapping area.

FIGURE 2. The Sacramento River at the upper end of the trapping area.
Photograph by John E. Riggs.

During most of the year and especially during the period of steelhead and fall-run king salmon migration, the lower Sacramento River is heavily laden with silt, which gives a light brown color to the water. During summer and fall, normal turbidity is increased by returned irrigation water, principally from rice fields between Colusa and Knights Landing. During winter and spring, muddy water is caused not only by silt from the main channel, but also by debris washed into the river by rain-swollen tributaries. However, during a dry winter the Sacramento River is comparatively clear in its lower reaches.

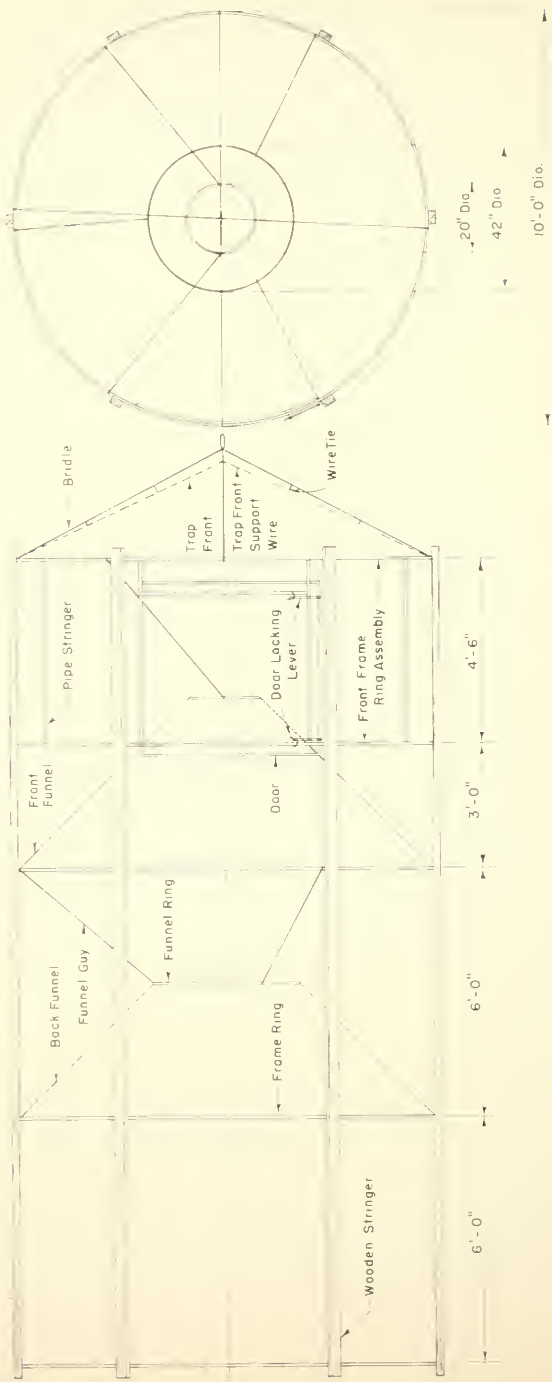

FIGURE 3. General diagram of wire fyke trap construction. The wire mesh covering is not shown.

CONSTRUCTION OF TRAP PARTS

General Description of Traps

The traps are essentially large cylinders, 10 feet in diameter and $19\frac{1}{2}$ feet in length (Figure 3). They are open at one end and contain two funnels, which act as a one-way passage for fish into a pot or impounding area. The traps are always fished with the back or open end downstream.[2] The two funnels face the same way, with the small openings upstream, and a fish must swim through both to enter the pot. The funnels and the exterior of the trap are covered with wire mesh netting. Captured fish are removed with a dip net through a door which opens into the pot.

The trap frame consists of five rings made of three-quarter-inch pipe. The rings are held rigidly in place by six 2 by 4 inch wooden stringers which extend the length of the trap. Two different sizes of wire netting are employed in the trap construction. One-inch mesh, 18-gauge stucco wire is used to cover the pot of the trap, which includes the front funnel. The remainder of the trap, including the back funnel, is covered with 2 by 3 inch mesh, 15-gauge salmon trap wire. When the coarser mesh was used to cover the impounding area there were too many casualties due to gilling, particularly among the steelhead. All pipe, wire netting, and other wires used are galvanized.

A completed trap weighs between 500 and 600 pounds and contains approximately \$100 worth of materials. With experienced personnel, it takes a two-man team about 16 hours to construct a trap, starting with prefabricated rings and the necessary materials and tools.

The Rings

The frame rings are 10 feet in diameter and approximately $31\frac{1}{2}$ feet in circumference. A convenient method of construction is to use standard 21-foot lengths of pipe. Each ring then consists of one and one-half lengths of pipe welded together. As an alternative to welding, a short length of three-quarter-inch diameter iron rod, bent to the proper radius, may be inserted into the ends of the pipes and the joint then secured with two or more quarter-inch diameter rivets on each side of the joint. In event of damage to a trap, a riveted ring can more easily be taken apart and reshaped. The original frame rings were shaped with a pipe bending jig at the Department's Elk Grove Fish Screen Shop. Since that time all new rings have been constructed by a commercial firm.

The small funnel rings, which are attached to the small end of the funnels, are made of three-eighths-inch diameter pipe. They are bent by hand and checked against a pattern. The ring for the back funnel opening has a diameter of 42 inches, while the front funnel has a 20-inch diameter.

---

[2] Throughout this report, "upstream", "forward", and "front" mean toward, or nearest to, the closed end of the trap; and "downstream", "rear", and "back" mean toward, or nearest to, the open end.

Front Frame Ring Assembly

The two front frame rings are assembled as a unit by welding four pieces of three-quarter-inch pipe between them. Two of these 54-inch long pipe stringers are welded to the rings 48 inches apart, to form a 48-inch high door opening for removing fish. The other two pipe stringers are welded between the rings opposite the door opening, to provide additional support (Figure 4). The door opening is completed by welding a 48-inch long section of pipe between the two stringers, parallel to, and 10 inches from, the upstream frame ring. The latter section of pipe is bent to conform with the shape of the frame rings. This provides a door opening 44 inches wide and 48 inches high. By having the front edge of the door opening 10 inches back from the upstream ring, an area is provided for overlapping and securing the netting covering the end of the trap to that covering the sides.

FIGURE 4. The front frame ring assembly with the wire mesh front in place, but not yet secured. *Photograph by Don A. LaFaunce.*

Pattern for Funnels and Trap Front

When cutting the wire netting to cover the funnels and front end of the trap, a great deal of time can be saved if a pattern is first marked on the ground or the floor. Satisfactory patterns for 10-foot diameter traps are shown in Figure 5. When used on a working surface the patterns are superimposed for convenience as shown in Figure 6.

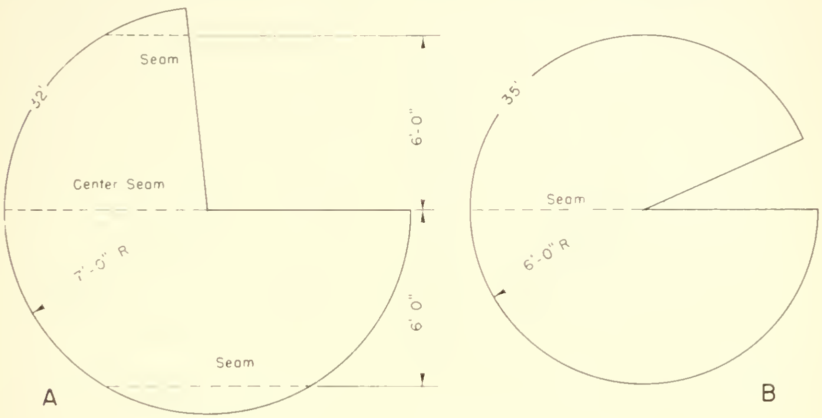

FIGURE 5. Pattern for funnels (A) and trap front (B).

The funnels are made as cones. The tip of the cone is cut off when the small funnel ring is attached. To lay out the funnel pattern, start at a focal point near the center of the pattern area and describe an arc, using a seven-foot radius. The radius of the pattern arc coincides with the length of the sides of the cone or funnel, assuming that the funnel is projected to an apex. The length of the arc described is 32 feet. The circumference of the trap frame ring to which the base of the funnel will be attached is 31½ feet. The additional six inches are to allow for overlapping the meshes at the center seam.

Next, draw radial lines between the focal point and the ends of the arc, completing the pattern. It was found to be more practical not to lay out, as part of the pattern, lines indicating material to be cut away from the apex of the cone, to install the small funnel rings. This material is cut away later, when the funnel rings are attached. For convenience, a center line may be drawn on the platform first. A center line is an aid in laying out the netting to cover the pattern. A common center line and focal point are also desirable when funnel patterns for more than one diameter of trap or funnel height are to be drawn on the same platform.

The trap front is a complete cone. A satisfactory pattern can be made using a 6-foot radius and a 35-foot arc. The base of a trap front cut on this pattern will fit snugly on a 10-foot diameter ring, five and one-half feet from the apex, measured along the sides of the funnel, and will also leave six inches of netting for overlapping the barrel of the trap. The trap front will have a height of about two feet, measured vertically from the base to the apex.

The Funnels

Material required for the front funnel is as follows:

1. one 10-foot diameter ring of $\frac{3}{4}$-inch pipe;
2. one 20-inch diameter ring of $\frac{3}{8}$-inch pipe;
3. one-inch mesh, 18-gauge stucco netting (72 inches wide, if possible);
4. 16-gauge galvanized wire for lacing.

Material required for the back funnel is as follows:

1. one 10-foot ring of $\frac{3}{4}$-inch pipe;
2. one 42-inch ring of $\frac{3}{8}$ inch pipe;
3. 6-foot wide 2-inch by 3-inch mesh, 15-gauge salmon trap netting;
4. 16-gauge galvanized wire for lacing.

To assemble a funnel, unroll the netting with one edge along the center line of the pattern. Weight it down with bricks, rocks, etc., and cut around the arc of the pattern. By cutting the netting an inch or two wider than the pattern a better fit can often be obtained on the frame ring, especially if the ring is not perfectly round. Roll more netting out on the other side of the center line, weight it down, and again cut around pattern. When the netting is cut, the pieces are laced together at the selvage edges with No. 16 galvanized wire. Figure 6 shows a funnel being cut and laced. The two netting edges formed by the radial pattern lines are not joined until after the material has been fitted on the frame ring. An additional small piece of netting is required at each side to cover the funnel pattern. Wherever possible, it is best to lace selvage edges together, since they are stronger than cut edges. Otherwise, it would be theoretically possible to construct the funnel out of three pieces instead of four, since the netting is six feet wide.

After the netting has been cut and laced, it is suspended by the apex, so that the base of the funnel is several inches off the platform. A 10-foot frame ring is then fitted to the inside of the base of the funnel, as shown in Figure 6B. The wire mesh is tied to the frame ring at about 30-inch intervals with temporary ties of No. 16 wire. Any irregularities in the funnel can then be corrected by slightly shifting the ring on the netting. The lapped portion of the center seam, formed by the two radial edges of the pattern, is secured by twisting the cut ends of the wires into the adjacent meshes. All of the wire ends must point toward the inside or center of the funnel, to eliminate any sharp projections in the pot of the trap, upon which the confined fish might cut themselves.

The small funnel ring is attached by setting the funnel on its base and putting the small ring over the apex, as shown in Figures 6C and 6D. A man can then crawl underneath the funnel, cut off the apex, allowing a sufficient overlap, bend the wire over the ring, and twist the cut edges through the adjacent mesh.

Figure 6 shows the construction of a front funnel made with $1\frac{1}{2}$-inch mesh netting.[3] The same pattern and procedure are used for the back funnel, except that it is made with 2 by 3 inch mesh netting.

[3] These photographs were taken before the mesh size was changed to one-inch mesh. The same construction procedure is followed, however, regardless of mesh size.

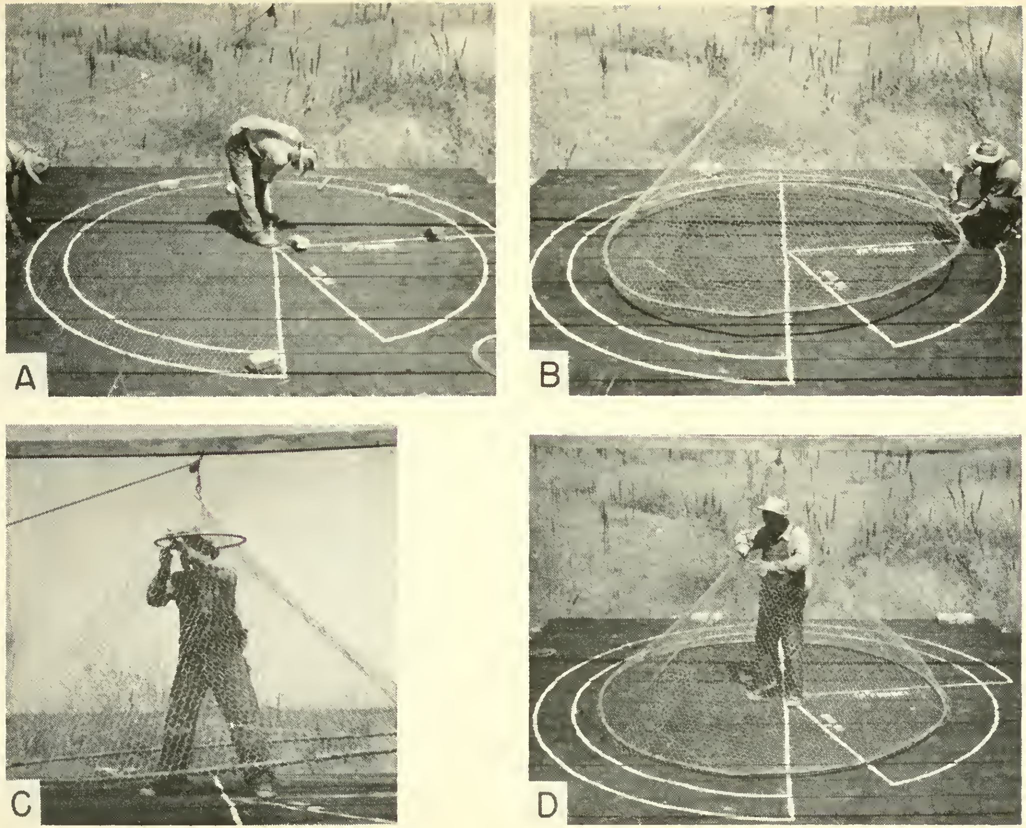

FIGURE 6. Assembling a funnel. A, cutting the netting using the painted pattern; B, the netting has been formed into a cone and the 10-foot frame ring is being installed; C, the frame ring has been installed and the small funnel ring is being fitted; D, the small ring is being laced into the funnel. *Photographs by John E. Riggs.*

Trap Front

The trap front forms the forward wall of the fish impounding area. In addition to the front frame ring assembly, a supply of one-inch mesh wire netting is required. It is constructed in the form of a cone, with the apex pointing upstream. This shape helps to shunt floating debris around the trap, and increases the volume of the impounding area.

Figure 5A shows a pattern for the trap front. The same general procedure is followed for cutting out and assembling the front as is used for the funnels. After the netting has been cut to fit the pattern and laced, it is suspended by the apex, and the frame ring assembly with the forward ring uppermost is slid beneath it. The two netting edges formed by the radial pattern lines are not joined until after the material has been fitted on the frame ring. The netting is then placed on the forward ring, leaving an overlap of six inches around the ring. The netting is then attached at about 30-inch intervals to the ring with temporary ties of No. 16 wire. After the netting has been attached and properly fitted to the ring, there will be an overlap of six inches at the center seam. The overlapping netting is then secured by twisting the cut ends into the adjacent meshes, the same as for the funnels. If the frame ring assembly is placed on edge after the wire mesh has been temporarily tied to the front ring, twisting the center seam wires becomes considerably easier. The ends of all wires should be left projecting toward the outside of the trap. Figure 4 shows a trap front and rings after the front has been completed.

Trap Assembly Jig

A great aid in the final assembly of each trap is a jig to hold the frame rings and funnels in place while the barrel is being covered with netting, and until the wooden stringers have been attached. The jig used included four lengths of one-inch diameter pipe, each 21 feet long. Three-eighths-inch diameter holes were drilled through the pipes at intervals representing the desired spacing of the trap frame rings. Holes for the frame ring next to the front end of the trap were omitted, since this ring was already part of a rigid assembly. The remainder of the jig consisted of 16 iron hook bolts. These bolts were made of three-eighths-inch material, with a bend at the end, to hook around the three-quarter-inch diameter frame rings (Figure 7). By holding the principal component parts of the trap frame rigid throughout the final assembly, the jig saved time and effort.

FINAL TRAP ASSEMBLY

One of the first steps in the final assembly of the trap is to attach the jig pipes to the frame rings. The front ring assembly, including the trap front netting, is placed on its side. The fifth or back frame ring is then placed against the front ring and each is marked identically at four equally spaced points around its circumference. The back ring is then laid aside temporarily. Next, the two funnels, including the frame rings, are nested against the rear ring of the front ring assembly and attached individually with temporary wire ties. The first of the jig pipes is inserted along the inside of these four rings and fastened with a hook bolt to the front ring, at one of the four marks.

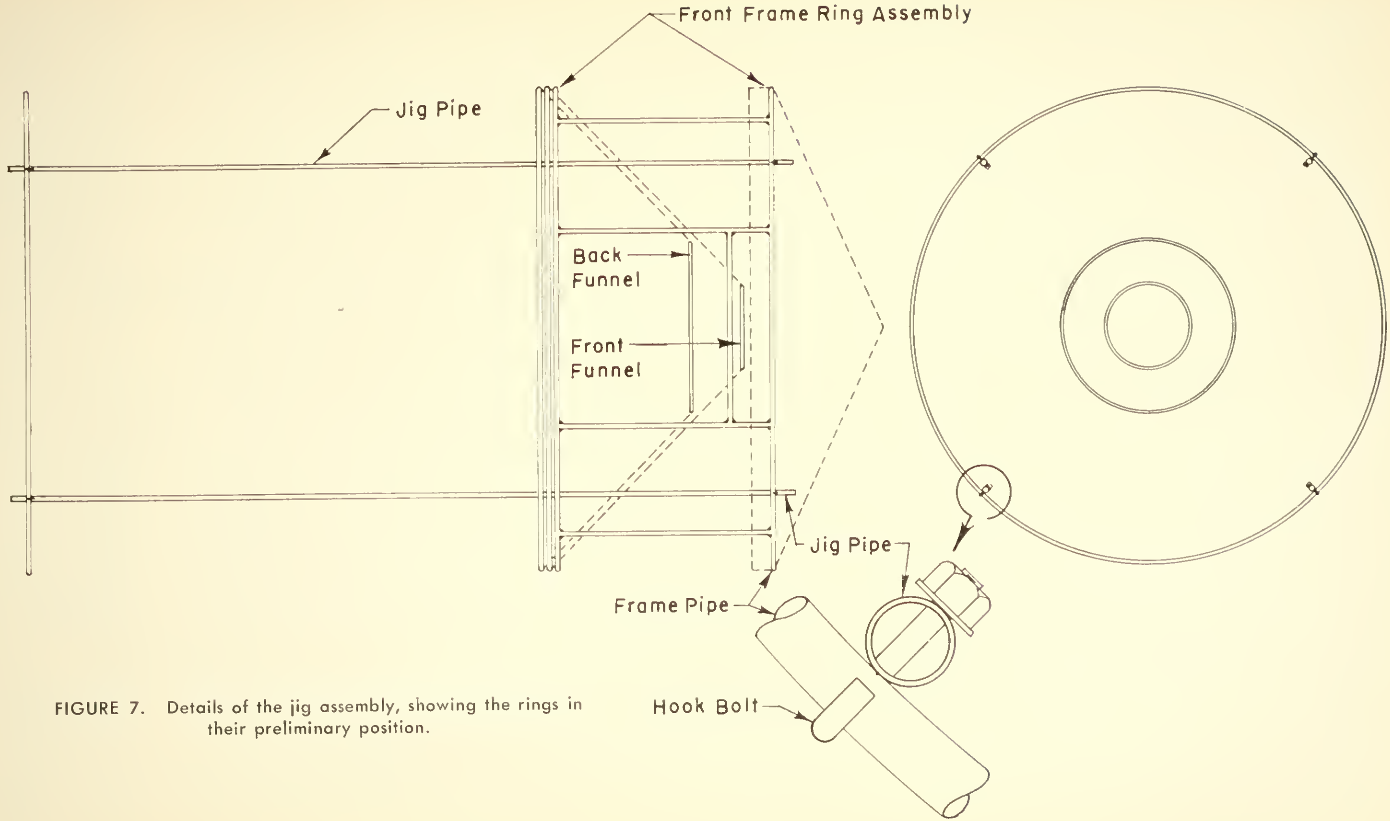

FIGURE 7. Details of the jig assembly, showing the rings in their preliminary position.

The back frame ring is then fastened to the other end of the jig pipe with a hook bolt, at one of the marks. A second jig pipe is now fastened to the opposite side of the frame rings, in the same manner. The entire assembly is then rolled one-quarter turn and the other two jig pipes are attached at the appropriate marks on the front and back rings. Figure 7 shows the assembly at this point. After all four pipes have been attached to the front and back frame rings, the temporary ties holding the funnels together are cut, and the funnels are shifted to their respective positions. They are then bolted in position to the jig pipes.

Two sizes of wire mesh netting cover the outside or barrel of the trap. Two strips of 2 by 3 inch mesh salmon trap wire, each six feet wide, encase the portion to the rear of the front funnel. The remaining section of the trap, the fish impounding area, is covered with a 6-foot and $1\frac{1}{2}$-foot strip of 1-inch mesh stucco wire netting. The $1\frac{1}{2}$-foot strip was made by splitting a 3-foot roll, since narrow rolls of stucco wire were not available. To prevent long sharp wires from protruding, all cuts should be made close to the twisted portions of the wire mesh. The two strips of netting are laced together before covering the trap. However, it is not advisable to lace the two different sizes of netting together, since this frequently causes buckling. Instead, they are laced simultaneously to the trap frame ring where they join. The barrel of the trap is covered by laying the laced strips side by side on the ground and then rolling the trap frame over them. As the frame rolls over the wire, the netting is laced firmly to the frame rings with No. 16 wire. Tying the netting to the rings with temporary ties of No. 16 wire, ahead of the lacing, often helps to space the netting. As the wire lacing attaches the netting covering the barrel of the trap to the frame rings, it also laces the funnel netting to the rings. The cut ends of the trap front netting overlap the barrel and are twisted into the meshes covering it as the trap covering and front are laced to the front frame ring.

An easy method of securing the wire mesh to the door opening is to trim the netting close along the *sides* of the door opening and then lace with No. 16 wire. When the netting is cut properly, there is in effect a selvage edge at every other mesh to lace through, since the twisted sides of each hexagonal mesh are parallel to the sides of the door opening. However, the netting at the *top* and *bottom* of the door opening should be cut long enough to wrap around the pipe stringers of the door opening, and the cut ends should be twisted into the adjacent meshes. All wire ends should be left on the outside of the trap. These cut ends should be kept as short as possible on the bottom of the door opening, so they will not foul the dip net while fish are being removed from the trap. The wire mesh is applied to the door frame itself in the same manner.

The Door

The door is hung on the inside of the trap from the top of the door opening frame, with hinges made of doubled strands of No. 16 wire. The door opening rope and the door locking levers complete the door assembly. See Figure 8 for details of locking levers. The door is opened inward by a rope running on the inside of the trap from the bottom of the door through a small pulley fastened to one of the

stringers above the door, thence to the outside of the trap. The door frame is made of three-eighths-inch pipe. It is 51 inches high and 50 inches wide. This allows the door to overlap the door opening by 3 inches at the sides and bottom. The door is bent to conform with the curvature of the door opening to assure a fish-tight fit when closed.

Attaching the Longitudinal Stringers

When all lacing is complete, the 2 by 4 inch stringers are fastened to the frame rings on the outside of the trap with No. 9 galvanized wire. One stringer is attached immediately above and another just below the door opening. The lower stringer should be at least two inches below the door opening to allow space for the door-locking levers. The remaining stringers are spaced equally around the trap. One-fourth-inch holes are drilled through the stringers to take the wire at the two end frame rings, so there will be no chance of slippage. The rest of the wire ties are wrapped around both pipe and board at each frame ring and twisted tight. The stringers are tied at all rings. The pipe jigs may now be removed. Next, the funnels are guyed to the frame rings with No. 9 wire. The front funnel guys should not interfere with fish removal or opening of the door.

The Bridle

The head cable bridle on the front of the trap is made with two pieces of quarter-inch cable. It is attached at four equally spaced points to the front frame ring and crossed in the center. The bridle

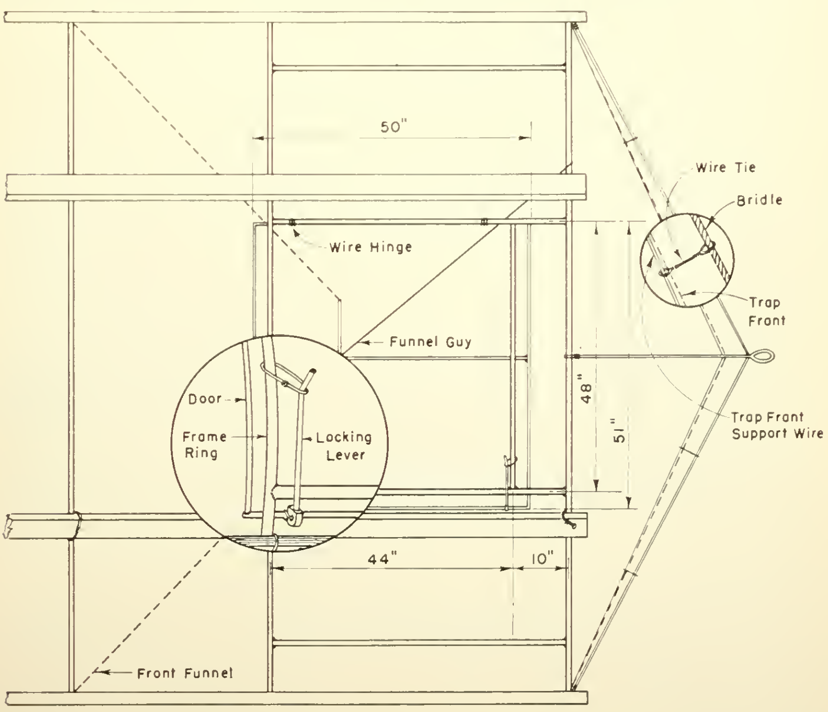

FIGURE 8. General diagram of the front of the trap, showing the door and bridle assembly.

cables are fastened together where they cross, with a three-eighths-inch cable clip. One of the cables is cut slightly longer than the other and a small loop is formed in it at the center, before the cable clip is attached. The head cable is later attached to this loop. The bridle cables are fastened to the frame ring with a half hitch and are secured by seizing with No. 16 wire or with a cable clip. On the Sacramento River, there was ordinarily no great strain on the bridle, so securing with cable clips was not necessary. The bridle should be made so that it clears the trap front by a few inches. To support the wire netting of the trap front, two pieces of No. 9 wire are fastened across the front of the trap on the inside of the wire mesh, directly opposite the bridle cables. These trap front supports are tied with short pieces of wire to the bridle at the center, and at one or two other points to each bridle cable. The ties should be long enough so that they will have a slight amount of slack when the bridle is fully extended (Figure 8). The head cable then pulls directly on the bridle and not on the wire netting. The purpose of the wire trap front supports is to keep the trap front netting from sagging, and to distribute any strain on the netting over a wide area and thus prevent breaking the mesh.

TRANSPORTING THE TRAPS

The traps are transported on a two-wheeled flat bed trailer, with an extended tongue (Figure 9A). Two lengths of 4 by 6 inch timber, each six feet long, are fastened crosswise to the ends of the trailer to support the traps. The trap is tied to the trailer with rope or wire. Figure 9B shows a trap loaded on the trailer.

When it is necessary to move a trap a short distance at the trapping site, a sled is used (Figure 9C). This sled consists of two lengths of 2 by 12 inch lumber for runners, each about 12 feet long. Three-inch angle iron was attached along the bottom and inside of the runners. The runners were spaced about four feet apart and held rigidly by sections of pipe welded between the pieces of angle iron. The trap is supported on the sled with two-by-fours attached across the top at each end of the wooden runners. A trap is easily rolled onto the sled because the sled is so low. The sled is pulled by a bridle made of quarter-inch wire rope. A heavy harness snap on the forward end of the bridle hooks the sled to the rear of an automobile. Traps have been easily moved as far as one mile with the sled. By using the sled rather than the more expensive trailer for these short hauls, it was permissible to leave the moving equipment at the fishing site permanently without fear of loss from vandalism.

On one occasion, it was necessary to move a trap by water. Four empty 50-gallon oil drums were attached to opposite sides of the trap, with two on either end. The four drums provided ample buoyance (Figure 9D). The trap was then towed with two outboard motor powered skiffs. One boat was powered by a 16-horsepower motor, the other by a 25-horsepower motor. This method is entirely satisfactory for moving a trap downstream, across the river, or a short distance upstream. Moving one upstream a long distance by this method would have been difficult.

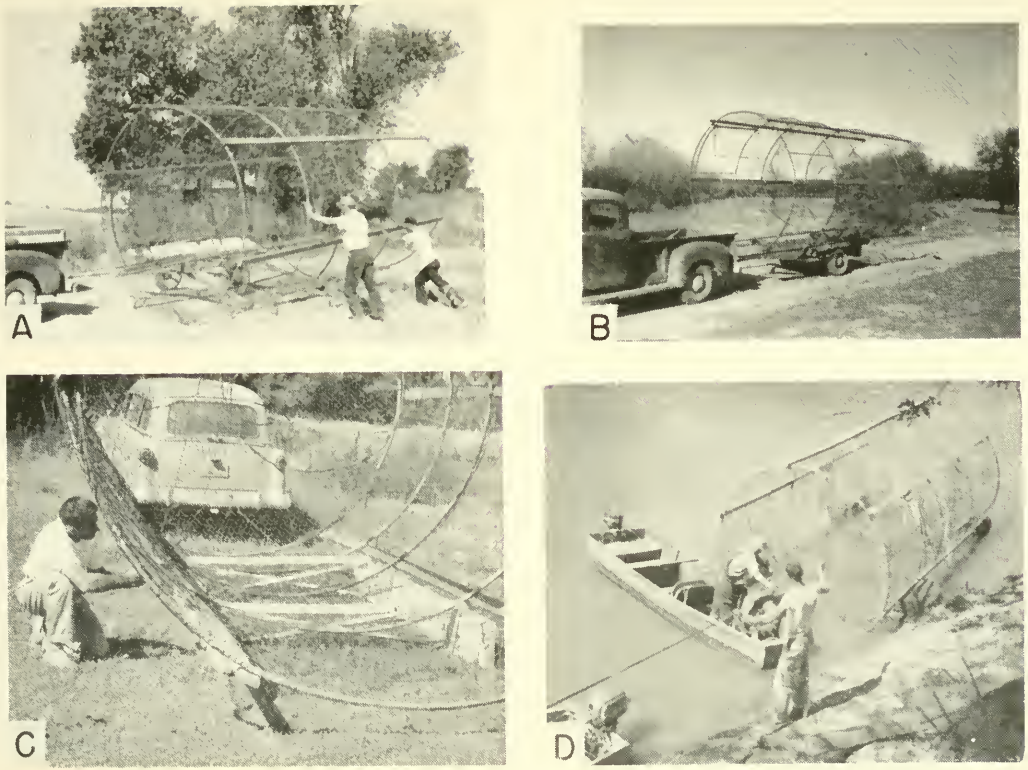

FIGURE 9. Transportation methods. A, rolling the trap onto the trailer; B, the trap in place on the trailer and ready to travel; C, the trap on the low sled; D, using empty oil drums as floats for water transportation. *Photographs A and C by Jahn E. Riggs; B, by Don A. LaFaunce; D, by Richard J. Hallock.*

OPERATING THE TRAPS

Placing Traps in the River

To aid in rolling the traps up and down the bank they are attached to two strands of No. 9 galvanized wire, which are called runner wires. The runner wires are wrapped around the trap before placing it into operation. These wires are attached to the second and fourth frame rings and to a stringer at the point where the two cross. A man holds each wire tight to keep the slack out of it while the rest of the crew rolls the trap onto the wires, until the desired number of wraps is made. The number of wraps will vary, depending upon the depth of fishing anticipated and the height of the river bank. Three or four are ample on the Sacramento River. By having a man hold each of the runner wires taut while they are rolled onto the trap, practically all of the undesirable slack is eliminated. The direction of wrap must be such that the trap, when being rolled up the bank, is rolled onto the wire.

After the runner wires have been attached, the trap is set on the bank above the desired fishing spot, open end downstream. One end of the head cable is then attached to a solid object on the bank, such as a stump, tree, or post, about 100 to 150 feet upstream. The free ends of the runner wires, coming off the bottom of the trap, are then fastened to strong stakes or trees on the bank, opposite the trap ring where they are attached. One end of a quarter-inch wire rope known as the pull cable is attached to the center ring with a clove hitch and cable clips where a stringer crosses it. The free end of the pull cable is attached to an automobile (or windlass, or whatever device is to be used in pulling the trap up and down the bank). The slack is taken out of the pull cable with the automobile, which is then slowly backed towards the river. As the car backs, the trap is rolled over the bank, with the cable kept tight. As the trap rolls down the bank, it unrolls the runner wires and rolls up the pull cable. The car is continued to be backed slowly and the trap allowed to roll to the water's edge. The free end of the head cable is attached to the trap bridle, using cable clips. The length of the head cable is quite important. If it is too short, the trap will shift on the runner wires when being rolled up and down the bank. If the head cable is too long, the weight of the cable, plus the water resistance, will have a tendency to make the trap stand on end. A head cable of 100 to 150 feet worked satisfactorily on the Sacramento River. If it was desirable to fish the traps deeper, or farther out in the river, the head cable was lengthened.

Adjusting the Door

When a trap is first put in the water, and as the water level changes during the season, it is usually necessary to adjust the door position so that captured fish may be removed. The trap is adjusted so that when the door is opened about one and one-half feet of water remains in the trap for the fish to swim in. Figures 10A, 10B, and 10C show a trap in a raised position, ready for the removal of fish. Adjustment is made by rotating the trap in place until it is in the desired position.

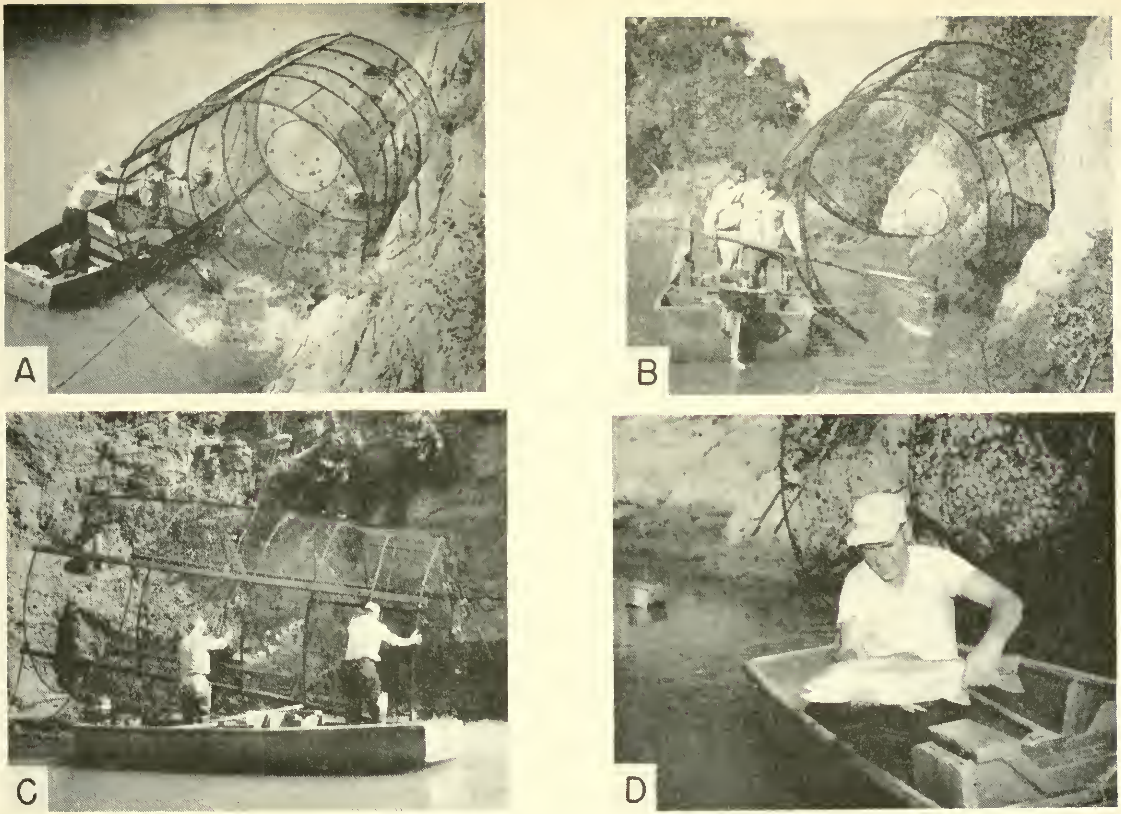

FIGURE 10. The trap in use on the river. A, rolling the trap out of the water; B, removing the fish with a dip net; C, view from the river side, showing the position of the skiff when the trap is lifted—minor repairs and cleaning are carried on in this position; D, the skiff is tied alongside the trap while the fish are removed and tagged. *Photographs A, C, and D by Gene P. LaFaunce; B, by Richard J. Hallock.*

Such adjustments are made by taking up or letting out the runner wires. A convenient method is to use a large hook, such as a hay hook, attached to a rope. The trap is hooked at one end, lifted until there is enough slack in the runner wire, which is then let out or shortened by the appropriate amount, fastened, and the hook removed. The operation is then repeated at the other end of the trap. This job usually requires two men on the bank, assisted by a man in a boat. If, for example, the adjustment requires shifting the trap several feet or one-half turn, it is necessary to let out or haul in the pull cable accordingly, by moving the automobile.

Fishing Sites

The traps were usually fished with the tops between six inches and one foot under the water surface and as close to a steep bank as possible. They were most successful in capturing fish when fishing this top 10 feet of the river near the shore. Various positions farther out in the river were tried, but were definitely not as productive, particularly in capturing steelhead. Also, the increased water velocities encountered away from the bank proved unduly harmful to the captured fish. However, the farther away from a bank the traps were fished, the deeper they were in the water. No attempts were made to fish the traps at any distance from shore, at any depth other than at the bottom of the river.

The most desirable fishing sites for all species captured were on the deep side of the river, where the bank was almost vertical. The high vertical bank also allowed the traps to be fished through considerable fluctuation in water level. Particularly good fishing areas were those where the river first straightened out after making a sharp curve. Several excellent trap locations were also available along fairly straight stretches of river, but always on the swifter, deeper side. One fishing site along a particularly brushy shore line was exceptionally good for catching large numbers of steelhead, but not salmon. At the beginning of the trapping at Fremont Weir in 1951, the traps were shifted continuously until enough sites which consistently produced good catches were found. From year to year, the river channel has changed, necessitating a relocation of a few fishing sites. Often just a simple movement of a trap 10 feet upstream or downstream has increased the catches to the desired level.

Tug boats traveling between Sacramento and Colusa pass this section of the Sacramento River at all hours of the day and night. Five-gallon cans painted red were used as buoys to mark the traps for the benefit of boat traffic and sport fishermen along the bank.

Safety Cables

There was always the possibility that the automobile brakes might not hold, or that the pull cable might snap. A safety cable was devised to keep the trap from rolling onto the tagging skiff and the tagging personnel, if such an accident occurred.

One end of the safety cable is attached to the trap at the center frame ring in the same manner as the pull cable, and the other end is fastened to a strong tree or a post on the bank. It is tied so that when fully extended the trap will be fishing at the proper depth. This fastening is *not* undone during normal fishing operations. Sufficient surplus

cable is kept to allow the trap to shift in a vertical direction as the water level changes during the season.

The safety cable plays in and out, off the top of the trap, in the same manner as the pull cable. When the trap is rolled up the bank to remove fish, the safety cable is also hauled in to keep it from tangling with the pull cable. As soon as the trap is in position to remove the fish, the safety cable is pulled tight and tied securely to the tree, stump, or post.

After the fish have been removed and the trap has been cleaned and inspected for holes, and any necessary repairs have been made (cleaning leaves and debris off the traps is accomplished quite easily by slapping the wire webbing with a paddle or small wooden club), the skiff is moved away from the trap. The safety cable is untied and the automobile driver then backs up, lowering the trap by its own weight. The safety cable plays out on its own until it tightens and stops the trap at the desired depth. The pull cable then goes slack and the driver disconnects it from the auto and ties it to a tree or post.

Because of the high, steep banks along this section of the Sacramento River, it was usually impossible for the driver of the automobile pulling the trap or replacing it in the water to see the men in the tagging skiff or to hear their shouted instructions. A safe procedure was to have a man in the boat and a man standing on the bank, where he could see and direct both the skiff and the automobile.

Snatch Blocks

To facilitate rolling the traps in and out of the water, six-inch steel snatch blocks were used. These pulleys were carried from trap to trap during the day's tagging. The suspended snatch blocks prevented the pull cable from cutting into the bank, with a resulting friction that would wear the cable and hamper the trap movement. If the cable had cut into the bank the traps would often not roll into the water on their own accord. When trees were handy, the snatch block was suspended from one of them. If no trees were available, a strong post was set in the bank and the pulley secured to it. In some instances, a steel tripod was used in conjunction with a post, to keep the cable clear of the ground. The tripods were made of three-inch angle iron, with 5-foot long legs.

Fishing Operations

After a night's fishing, the trap should be rolled up the bank very slowly. If it is apparent that there is a large catch, overcrowding of the fish is avoided by stopping the trap while it is fairly deep in the water. Fish can then be dipped out and tagged until they are fairly well thinned out. The trap can then be rolled a little farther up the bank and the process repeated.

If the trap is rolled too far or too fast, there is likely to be a panic during which even medium-sized fish may injure themselves by swimming into the mesh at great speed. With the possible exception of shad, the only panicking of fish was that caused by raising the trap and the resulting confinement of the fish in shallow water. If the trap is moved slowly, the fish remain relatively quiet. It is usually good technique to remove the larger fish and any more active "trouble makers" as soon as possible.

SPECIES OF FISHES CAPTURED

Steelhead Trout

Adult steelhead migrate into the upper Sacramento River during most months of the year. The first migrants each season pass the trapping area in mid-June, and the run is continuous until the middle of the following March. Very few, if any, adult steelhead move from the Delta into the upper Sacramento River between the middle of March and the middle of June. The bulk of the run passes the trapping area between early August and late November. The peak of the run usually occurs near the end of September.

Sacramento River steelhead are generally smaller in size than those found in California's coastal streams, usually averaging between three and six pounds, with fish up to eight pounds being common. Steelhead over 13 pounds are rare in the Sacramento River.

The size of the steelhead run has varied between 15,000 and 31,500 during the past four years.

The seven traps fished at Fremont Weir were very effective in capturing large numbers of live adult steelhead. The percentage of the total run trapped has varied between 10 and 20 percent (Table 1). Trapped fish are in excellent condition, with very few visible marks or bruises which might indicate any attempt by the fish to swim against the wire webbing in an effort to escape. Steelhead were left in the traps for as long as three days and still remained in excellent condition. Marked fish were placed in the traps from time to time to find out if they were escaping once they had entered the trap. None of the marked fish ever escaped, although it was possible for them to swim downstream and out of the traps through the open funnels. Over 160 steelhead have been taken in a single trap with 24 hours of fishing. Steelhead entered the traps during daylight hours, as well as during hours of darkness. However, by far the greatest catches were made at night. During the peak of the run, fair numbers of fish entered the traps during the daytime.

The traps are somewhat selective with regard to sizes of steelhead captured, but not nearly to the degree that they are with king salmon. When the steelhead run consists of a large number of comparatively small individuals, a greater percentage of the total run is captured. It has also been demonstrated by the trapping that the average size of steelhead decreases at the peak of the run, with a preponderance of larger fish migrating upstream at the beginning and end of the season. An excellent cross section of the steelhead population, over 12.5 inches in length, has been trapped each year at Fremont Weir. Fish 12.5 inches in length represent the minimum size tagged, although the minimum size trapped is 11 inches. During the past two years, examination of steelhead upstream from Fremont Weir, at Coleman Fisheries Station holding ponds on Battle Creek, at Clough Dam Counting Station on Mill Creek, and while doing creel census work on the main stem of the Sacramento River, has revealed an almost identical percentage of tagged fish.

TABLE 1

Numbers of Adult Steelhead Trapped in the Sacramento River Near Fremont Weir, Seasons of 1953-54 Through 1956-57

Month	1953-54[1]			1954-55[2]			1955-56[3]			1956-57[4]		
	Number of trap hours	Number of steelhead trapped	Catch per one hundred trap hours	Number of trap hours	Number of steelhead trapped	Catch per one hundred trap hours	Number of trap hours	Number of steelhead trapped	Catch per one hundred trap hours	Number of trap hours	Number of steelhead trapped	Catch per one hundred trap hours
July	1,687	23	1.36	1,581	78	4.93	2,488	51	2.05	1,550	3	0.19
August	3,923	523	13.33	3,606	591	16.39	3,529	667	18.90	3,799	371	9.76
September	3,410	861	25.25	3,636	3,545	97.50	3,548	1,300	36.64	3,296	1,829	55.49
October	3,489	471	13.53	3,441	1,521	44.29	3,168	709	22.38	3,736	1,443	38.62
November	2,760	104	3.77	2,075	284	13.69	2,066	142	6.87	2,198	189	8.60
December	2,810	82	2.89	860	67	7.79	716	24	3.35	1,154	40	2.75
January	2,304	57	2.47									
February	812	8	0.99	189	17	8.99						
March	1,416	4	0.28									
April	648	0	0.00									
May	672	0	0.00									
June	1,008	3	0.30									
Totals	24,960	2,136		15,388	6,103		15,515	2,893		16,033	3,875	-

[1] Estimated total run in the Sacramento River system above the mouth of the Feather River = 15,000.
[2] Estimated total run in the Sacramento River system above the mouth of the Feather River = 30,000.
[3] Estimated total run in the Sacramento River system above the mouth of the Feather River = 31,500.
[4] Estimated total run in the Sacramento River system above the mouth of the Feather River = 20,000.

King Salmon

Adult king salmon migrate into the upper Sacramento River system during all months of the year. Although there is a continuous movement of salmon past the Fremont Weir trapping site, there are three periods each year when the intensity of the migration is greatly increased. These peaks in the migration represent three distinct runs of winter, spring, and fall fish. Most of those moving upstream between the peaks are apparently either early or late segments of one of the three main runs.

The movement of winter and spring-run salmon is fairly continuous, but with considerable overlap, and it is difficult to distinguish clear-cut peaks in their migration past the trapping site. However, even though they move up the river at about the same time, these two groups of fish separate in the upper river in accordance with time and place of spawning.

Most of the winter-run fish spawn during May and June, in the upper portion of the main stem of the Sacramento River, between Anderson and Keswick Dam.

Spring-run fish spawn principally in late August and September. Spawning takes place primarily in the upper reaches of the Sacramento River above Red Bluff, and in the higher reaches of the larger tributaries such as Butte, Deer, Mill, and Battle creeks.

The fall run, which is larger in numbers than the other two combined, peaks at Fremont Weir near the last week of September. The bulk of these fish pass the trapping site between the middle of August and the early part of November. Most of the fall-run fish spawn between the middle of October and the latter part of December, with the greatest spawning activity taking place near the middle of November. Spawning takes place in the Sacramento River from a short distance below Chico to Keswick Dam, and in the lower reaches of practically all suitable tributary streams.

Based on tagging at Fremont Weir, salmon carcass counts in the upper river, and tag recovery data, the fall run of king salmon in the Sacramento River system, above its confluence with the Feather River, has varied between 123,463 and 446,000 fish during the period from 1953 through 1956. The traps as fished were effective in capturing large numbers of live adult king salmon. All salmon captured were in excellent condition insofar as damage caused by the traps was concerned, even when they were left in the traps as long as three days. Marked fish placed in the traps from time to time showed that these fish did not escape once they entered the trap. Kings were caught primarily at night, even during the height of the run.

However, the traps were not nearly so effective for king salmon as they were for steelhead trout. While the traps captured between 10 and 20 percent of the steelhead run each year, only 1 percent of the salmon run was captured using the same traps and with the same fishing effort (Table 2). The traps were considerably more size selective with salmon than with steelhead, and a preponderance of small fish was captured in the traps. This size selectivity was brought to light when measurements were made of salmon upstream from the trapping site, while doing carcass examination on the spawning beds, during spawning operations at Coleman Station, and while counting fish at Mill

TABLE 2

Numbers of Adult King Salmon Trapped in the Sacramento River Near Fremont Weir, Seasons of 1953-54 Through 1956-57

Month	1953-54[1]			1954-55[2]			1955-56[3]			1956-57[4]		
	Number of trap hours	Number of salmon trapped	Catch per one hundred trap hours	Number of trap hours	Number of salmon trapped	Catch per one hundred trap hours	Number of trap hours	Number of salmon trapped	Catch per one hundred trap hours	Number of trap hours	Number of salmon trapped	Catch per one hundred trap hours
July	1,687	95	5.63	1,581	203	12.84	2,488	356	14.31	1,550	30	1.94
August	3,923	713	18.17	3,606	636	17.64	3,529	1,038	29.41	3,799	226	5.95
September	3,410	1,885	55.28	3,636	1,122	30.86	3,548	1,638	46.17	3,296	518	15.72
October	3,480	1,087	31.24	3,441	1,012	29.41	3,168	603	19.03	3,736	449	12.02
November	2,760	244	8.84	2,075	315	15.18	2,066	182	8.81	2,198	128	5.82
December	2,840	85	2.99	860	69	8.02	716	30	4.19	1,454	32	2.20
January	2,304	11	0.48									
February	812	46	5.67	189	7	3.70						
March	1,416	183	12.92									
April	648	50	7.72									
May	672	40	5.95									
June	1,008	34	3.37									
Totals	24,960	4,173		15,388	3,364	--	15,515	3,847	--	16,033	1,383	--

[1] Estimated total fall run in the Sacramento River system above the mouth of the Feather River = 446,000.
[2] Estimated total fall run in the Sacramento River system above the mouth of the Feather River = 347,000.
[3] Estimated total fall run in the Sacramento River system above the mouth of the Feather River = 325,000.
[4] Estimated total fall run in the Sacramento River system above the mouth of the Feather River = 123,463.

Creek Counting Station. The measurements revealed that the average size of fish in the runs was much greater than the average size of fish captured in the traps. This size selectivity of fish for tagging purposes resulted in a poor sample of the run being tagged, and made a reliable estimate of the total population much more difficult. A poor random sample of the run by the traps was also indicated by a great variance in the tagged to untagged ratios of salmon observed in the main stem of the Sacramento River and in the various tributaries.

The trapping site was not ideally located for a population study of Sacramento River salmon which migrate above its confluence with the Feather River. The tagged fish, some of which were released only one-half mile above the mouth of the Feather River, often moved back down the Sacramento River and spawned in the Feather River and even in the American River, some 20 miles below.

Silver Salmon

In March, 1956, 43,025 yearling silver salmon were released in Mill Creek, one of the principal tributaries of the Sacramento River. These fish were introduced in an effort to establish a run of silvers in the Sacramento River system.

During the months of August, September, and October, 1956, a total of 437 of these silvers was captured in the traps. The run peaked in late August. All fish captured were small males, measuring between 13 and 20 inches. Prior to this time there was only one authentic record of a silver salmon being taken in the Sacramento-San Joaquin River system. Subsequent examination of silvers in the upper river, during 1956, showed that approximately 11 percent of the run had been tagged, or that the run totaled about 3,220 fish. This indicates that the traps are about as effective in capturing silvers of this size (13 to 20 inches) as they are in capturing steelhead.

Striped Bass

Each spring a spawning run of adult striped bass moves out of the Delta into the Sacramento River. A significant portion of this run passes Sacramento and turns off into the Feather River. The remainder migrates on up the Sacramento River and a few are caught by anglers each summer at least as far upstream as Cottonwood. The peak of this spring migration passes Fremont Weir in April and early May.

The traps were not fished during the period of striped bass migration, except during a year and one-half of continuous operation between July, 1953, and December, 1954. No reliable figures regarding the size of the adult striped bass runs past Fremont Weir are available, so it is difficult to estimate the real effectiveness of the traps in capturing this species. In other words, it is possible that a good portion of the fish which passed the trapping area was captured in 1954, while on the other hand the numbers caught might represent but a small segment of the run. A total of 723 adult striped bass was captured during the month of April, 1954, with only 648 hours of trap fishing, when not more than four traps were operated at one time. On April 21, 1954, a total of 300 striped bass was trapped in one night's fishing with but four traps in operation. A total of 108 striped bass was taken in 672 trap hours of fishing in May, 1954 (Table 3).

TABLE 3

Numbers of Striped Bass Trapped in the Sacramento River Near Fremont Weir, July, 1953, Through June, 1954

Month	Number of trap hours	Number of striped bass trapped	Catch per one hundred trap hours
July	1,687	16	0.95
August	3,923	7	0.18
September	3,410	4	0.12
October	3,480	4	0.11
November	2,760	0	0.00
December	2,840	0	0.00
January	2,304	2	0.09
February	812	0	0.00
March	1,416	2	0.14
April	648	723	111.57
May	672	108	16.07
June	1,008	103	10.22
Totals	24,960	969	--

Striped bass captured in the traps are in excellent shape, and they take the confinement quite well. Bass up to an estimated 35 to 40 pounds have been taken in the traps. The bass appear to enter the traps primarily during hours of darkness. However, the traps were not emptied enough in the daytime, during the period of striped bass migration, to be certain.

Shad

The traps were exceptionally effective in capturing large numbers of adult shad during their annual spring migration up the Sacramento River. The peak of this spawning run passes the trapping area in May. Shad were the only fish captured which could not live for any length of time in the traps. The traps were emptied each morning after 24 hours of fishing and practically all of the shad trapped with this method of operation were dead. The shad were not damaged externally to any extent by the traps, and usually the only visible mark on dead fish was a slight redness about the mouth and head. It appeared as though the shad had either pointed their noses into one of the wire meshes and swam, without gilling themselves, until dead, or had made a series of rushes against the wire webbing, eventually inflicting fatal injuries.

Live shad could probably be obtained with these traps if they were emptied often enough, for example, on an hourly basis. It also appears possible that if the impounding area of the trap had been constructed with a smaller mesh and perhaps in the shape of a sphere, in which shad could not find a corner into which to poke their noses, they might swim around in a continuous circle without injuring themselves. This was not tried. Instead, the trapping operation was curtailed during the height of the shad run, to prevent a possible large loss.

Shad were caught principally during hours of darkness but during the peak of the run good numbers were also taken in the daytime.

Other Fishes Captured

Several other species of fishes were captured from time to time in the traps. Among those appearing most frequently were the catfishes,

primarily white catfish (*Ictalurus catus*), channel catfish (*Ictalurus punctatus*), and occasionally brown bullhead (*Ameiurus nebulosus*). Catfish were numerous at times in the trapping area, and large catches were made with commercial-type catfish nets of smaller meshed cotton webbing. The large traps set for steelhead and salmon were surprisingly ineffective in capturing catfish.

Largemouth bass (*Micropterus salmoides*) and smallmouth bass (*Micropterus dolomieu*) were often captured, particularly in the spring and fall months, but never in any quantity. Only one sturgeon has been captured in the traps to date. This was a 460-pound white sturgeon (*Acipenser transmontanus*) measuring over nine feet in length, captured during the fall of 1955. The sturgeon population of this section of the Sacramento River is unknown, and thus the effectiveness of the traps for this fish remains a mystery. However, it is doubtful that the traps are very effective in capturing sturgeon.

Three species of Pacific salmon, other than kings and silvers, have also been taken in the traps. Between 1951 and 1956, a total of 31 chum salmon (*Oncorhynchus keta*), 10 pink salmon (*O. gorbuscha*), and 3 sockeye salmon (*O. nerka*) was captured. These fish were probably strays, since only a few are observed each year in the Sacramento River system.

Miscellaneous fishes appearing in the traps include western suckers (*Catostomus occidentalis*), splittail (*Pogonichthys macrolepidotus*), hardhead (*Mylopharodon conocephalus*), greaser blackfish (*Orthodon microlepidotus*), Sacramento squawfish (*Ptychocheilus grandis*), carp (*Cyprinus carpio*), black crappie (*Pomoxis nigromaculatus*), brown trout (*Salmo trutta*), bluegill (*Lepomis macrochirus*), tule perch (*Hysterocarpus traski*), and Pacific lamprey (*Entosphenus tridentatus*). None of these species was ever numerous in the catches.

SUMMARY

This article describes the construction and use of large cylindrical fish traps and their effectiveness in capturing king salmon, steelhead trout, silver salmon, striped bass, American shad, and other species of fishes in the Sacramento River.

The traps are 10 feet in diameter and 19½ feet long, open at one end, and contain two funnels which act as a one-way pass into a pot or impounding area.

Detailed material lists and construction directions are given, together with fishing and transportation methods.

The traps are fished in the Sacramento River along steep dirt banks where the water is commonly 20 feet deep a few feet from shore. The flow is usually between 5,000 and 10,000 cubic feet per second, with velocities of 2 to 3 feet per second near the shore.

Seven of these traps fished at Fremont Weir captured from 10 to 20 percent of the total run of steelhead. One percent of the king salmon run and, in 1956, approximately 11 percent of the silver salmon run was captured. These three species were in good condition, with no evident injuries. Considerable mortality was experienced by the American shad.

FISHES COLLECTED IN THE TROPICAL EASTERN PACIFIC, 1954[1]

HAROLD B. CLEMENS
Marine Fisheries Branch
California Department of Fish and Game

INTRODUCTION

This paper is concerned with marine fishes of Central and South America and the Galapagos Islands collected incidental to tuna tagging operations conducted from the tuna clipper M. V. MAYFLOWER during the period February 13 to June 9, 1954 (California Department of Fish and Game, Cruise Report C-2-54). In all, some 5,000 specimens were preserved frozen or in formalin and brought to the California State Fisheries Laboratory for identification and dispositon. From these, 62 families containing 137 species in 115 genera have been identified.

The present collection supplements that made from the tuna clipper M. V. INTREPID during 1952 and 1953 (Clemens, 1955) and should aid materially in achieving a better understanding of the habits of these tropical species, as well as of their geographical distributions.

METHODS OF CAPTURE

Several methods of capture were employed to sample a variety of habitats. These methods were:

1. Hook and Line.
   A. Trolling With Feathered Jigs and Plastic Squids.

      Trolling, while cruising between different fishing areas and bait grounds, resulted in the capture of several specimens found relatively near the surface of the water. It was by this method that barracuda, *Sphyraena idiastes*, station 17; a rainbow runner, *Elagatis bipinnulatus*, station 17; and bullet mackerel, *Auxis thazard*, station 11, were taken at the Galapagos Islands. In addition, a dolphinfish, *Coryphaena hippurus*, station 54, was caught off Colombia and a bonito, *Sarda velox*, station 44, off Panama by trolling.

   B. Bottom Fishing With Handlines.

      Handlines were employed to good advantage when the vessel was anchored or drifting in water less than 400 feet deep. The use of various sized hooks baited with live or cut bait resulted in the capture of many species dwelling at or near the bottom. At station 47 off Colombia three species were caught with a handline in 300 feet of water. Of these, only one, a snapper, *Lutjanus peru*, was previously known to science. A second, a scorpaenid, has since been named *Pontinus clemensi* (Fitch, 1955), while the third, a serranid, *Epinephelus*, is being studied by Dr. Boyd W. Walker, University of California, Los Angeles. The remoras have also been included in this category, though for the most part they were removed from sharks caught on handlines. One exception, however, was a *Phtheirichthys lineatus*, station 22, captured off Panama. This fish was taken under the night light in a dip net—no sharks were noted in the vicinity.

   C. Rod and Reel.

      A good deal of rod and reel fishing was carried out whenever the opportunity arose and several of the more "gamy" species found in relatively

[1] Submitted for publication April, 1957.

shallow water or near the surface were taken: cabrilla, *Epinephelus analogus*, station 1, off Panama; white spotted bass, *Paralabrax albomaculatus*, station 12, at the Galapagos Islands; and dolphinfish, *Coryphaena equisetis*, station 54, off Colombia.

D. Miscellaneous.

The Pacific amberjack, *Seriola colburni*, station 49, taken off Colombia were caught on squid poles—stout bamboo poles with short lines attached. Snag hooks were used to capture mackerel scad, *Decapterus*, station 21, at Malpelo Island.

II. Bait-net Hauls.

Tuna clippers use a large quantity of live bait in normal fishing activities. This bait is captured in relatively shallow water near islands or continental land masses by means of a large encircling type bait net. Each haul of this net was closely observed for specimens. On this particular trip, bait hauls made in the Gulf of Panama (stations 5, 25, 27, 45, and 55) resulted in especially good catches of sciaenids, engraulids, and carangids. One of the more rare specimens taken in a bait-net haul was a goby, *Tyntlastes brevis*, at station 45.

III. Examination of Stomach Contents.

This method resulted in the collection of various surface and deep sea forms that were not acquired in any other manner. For the most part stomachs examined were from oceanic skipjack, *Katsuwonus;* black skipjack, *Euthynnus;* and yellowfin tuna, *Neothunnus*. However, the specimens listed for station 2 were from a dolphinfish, *Coryphaena hippurus*, captured off Nicaragua.

IV. Dipnetting Under a Night Light.

After a day of good fishing, the tuna clippers frequently drift all night and start fishing again the next morning. This provides an excellent opportunity to suspend a bright light over the side of the vessel and dipnet the specimens attracted. Use of a night light resulted in the capture of many larval and post-larval forms, as well as larger fishes preying upon them. Larval bullet mackerel, *Auxis*, are usually the most numerous of the fish attracted to the night light. No special attempt was made to collect large numbers of *Auxis*, yet over 1,600 were taken; as many as 419 were dipped in a few hours at Malpelo Island, station 21. Other species commonly attracted to the night light were flying fish, Exocoetidae; lizardfish, Synodidae; lanternfish, Myctophidae; mullet, Mugilidae; and pomacentrids, Pomacentridae. Two of the more unusual species dipnetted at the Galapagos Islands were an eel, *Garmanichthys bicollaris*, station 12, and a snake mackerel, *Nealotus tripes*, station 13.

In actual practice several of the above-mentioned methods were often employed in the course of a particular evening. For example, on March 8, 1954, at the Galapagos Islands, station 12, the night light was put over the side of the vessel and a dip net made ready. Next, two handlines baited with cut bait were set out to fish. The collector then watched for specimens to appear under the night light, while live bait casting with rod and reel and periodically checking the handlines. As a result, one serranid, *Hemilutjanus macropthalmos*, and two wrasses, *Pimelometopon darwini*, were caught on the handlines, while six white spotted bass, *Paralabrax albomaculatus*, were taken on rod and reel and over 100 specimens representing 12 families were captured in a dip net under the night light.

LOCATIONS OF THE COLLECTING STATIONS

The magnitude of the area covered and approximate location of each collecting station within the area are presented in Figure 1. Table 1 contains collection data for all stations.

LIST OF SPECIMENS COLLECTED

The list of specimens collected (Table 2) has been arranged systematically by family and alphabetically by genus within each family, with slight modification of the classification system of the California

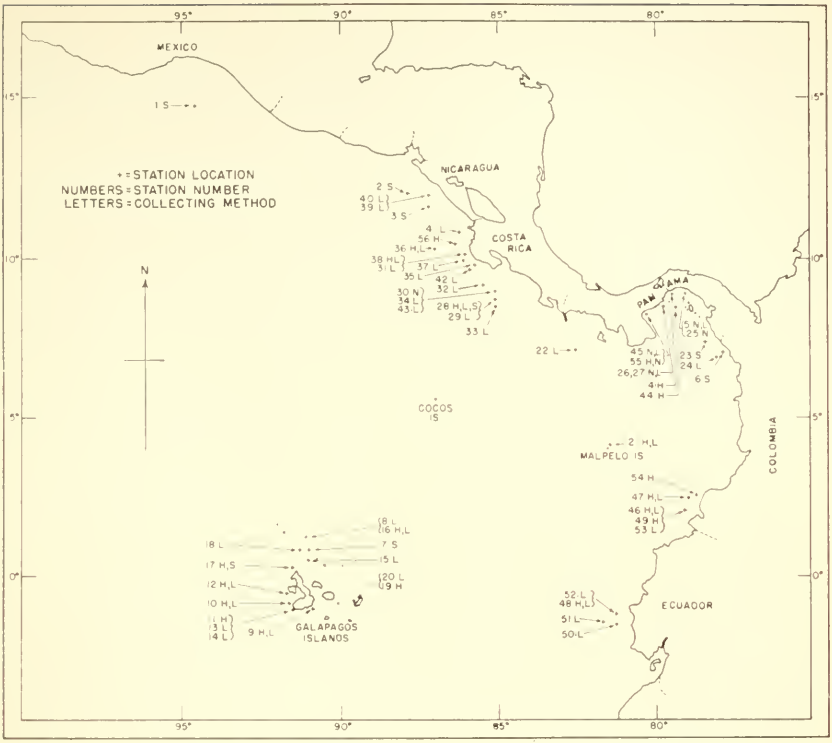

FIGURE 1. Chart of the area covered during a cruise of the MAYFLOWER, February 13 to June 9, 1954. Collecting localities, station numbers, and collecting methods are indicated. Collecting methods are H—hook and line, N—bait net, L—night light, and S—stomach contents.

Academy of Sciences. The scientific names follow the terminology of Meek and Hildebrand (1923-28) and Hildebrand (1946), except for those groups of fishes on which recent revisions were available.

A letter and one or more pairs of numbers follow each scientific name (Table 2). The letter refers to the collecting method listed in Table 1. The first of each pair of numbers is a station number and the second, in parentheses, represents the number of specimens of that species collected at that station. Thus, under family Clupeidae, it will be seen that two (2) specimens of *Odontognathus panamensis* were collected in a bait net at station 55. Table 1 informs the reader that station 55 was occupied on May 21 and 22 off the coast of Panama in five fathoms of water.

At most of the night light stations postlarval, juvenile, and young fish were taken. The specific identification for some of these has not yet been determined.

Most of the specimens listed have been placed in the Fish Collection, Department of Zoology, University of California, Los Angeles; others have been retained at the California State Fisheries Laboratory, Terminal Island, or have been sent to individuals or institutions specializing in a particular species or group.

TABLE 1

Station Data M. V. MAYFLOWER Cruise, February 13 to June 9, 1954

Station No.	Date	General locality	Latitude	Longitude	Collecting method*	Water surface temp. (Degrees F.)	Water depth
1	February 19	Mexico	14° 43′ N.	94° 38′ W.	S	--	1,000+ fms.
2	February 21	Nicaragua	11° 58.5′ N.	87° 49′ W.	S	--	1,000+
3	February 21	Nicaragua	11° 38′ N.	87° 09′ W.	S	--	110
4	February 24	Panama	8° 57′ N.	79° 34′ W.	H	77	10
5	February 24-27	Panama	8° 58′ N.	79° 10′ W.	N, L	76.5	15–30
6	February 28	Colombia	7° 00′ N.	77° 50′ W.	S	--	700
7	March 4	Galapagos Islands	0° 44.5′ N.	90° 47′ W.	S	82	500
8	March 4	Galapagos Islands	1° 15′ N.	91° 06′ W.	L	81	1,000+
9	March 6	Galapagos Islands	1° 09′ S.	90° 52′ W.	H, L	82	1,000+
10	March 7	Galapagos Islands	0° 55′ S.	91° 32.5′ W.	H, L	82	1,000+
11	March 8	Galapagos Islands	0° 59.5′ S.	91° 31′ W.	H	81	1,000+
12	March 8	Galapagos Islands	0° 29.5′ S.	91° 37′ W.	H, L	81	25
13	March 9	Galapagos Islands	1° 02′ S.	91° 30.5′ W.	L	81	1,000+
14	March 11	Galapagos Islands	1° 03′ S.	91° 29′ W.	L	79	1,000+
15	March 12	Galapagos Islands	0° 35.5′ N.	91° 04.5′ W.	L	80	1,000+
16	March 13	Galapagos Islands	1° 15′ N.	91° 06′ W.	H, L	81	1,000+
17	March 16	Galapagos Islands	0° 16.5′ N.	91° 37′ W.	H, S	80	1,000+
18	March 17	Galapagos Islands	0° 48′ N.	91° 16′ W.	L	79.5	1,000+
19	March 20	Galapagos Islands	0° 53.5′ S.	89° 37′ W.	H	79	15
20	March 20	Galapagos Islands	0° 47′ S.	89° 31′ W.	L	79	30
21	March 24	Malpelo Island (Col.)	3° 57′ N.	81° 35′ W.	H, L	81	80
22	March 26	Panama	7° 06.5′ N.	82° 36′ W.	L	83	1,000+
23	March 28	Panama	7° 19′ N.	78° 26.5′ W.	S	80	740
24	March 28	Colombia	6° 51′ N.	78° 07′ W.	L	80	1,000+
25	March 30	Panama	8° 50′ N.	78° 55′ W.	N	78	4
26	March 30	Panama	8° 25′ N.	79° 45′ W.	L	78	9
27	April 2	Panama	8° 25′ N.	79° 45′ W.	N	78	9
28	April 4	Costa Rica	8° 43′ N.	85° 07′ W.	H,L,S	85	1,000+
29	April 5	Costa Rica	8° 43′ N.	85° 07′ W.	L	85	1,000+
30	April 6	Costa Rica	8° 53′ N.	85° 07′ W.	N	85	1,000+
31	April 8	Costa Rica	10° 04′ N.	86° 01′ W.	L	86	690
32	April 10	Costa Rica	9° 09′ N.	85° 32′ W.	L	84	1,000+

33	April 11	Costa Rica	8° 18′ N.	85° 07′ W.	L	84.5	550
34	April 12	Costa Rica	8° 58′ N.	85° 07′ W.	L	84	1,000+
35	April 13	Costa Rica	9° 43′ N.	85° 47.5′ W.	L	85	900
36	April 14	Costa Rica	10° 13′ N.	85° 57.5′ W.	H, L	85	140
37	April 15	Costa Rica	9° 55′ N.	86° 08′ W.	L	85	520
38	April 16	Costa Rica	10° 07′ N.	85° 52.5′ W.	H, L	82	80
39	April 18	Nicaragua	11° 48′ N.	87° 09′ W.	L	82	59
40	April 19	Nicaragua	11° 42.5′ N.	87° 09′ W.	L	82	100
41	April 21	Costa Rica	10° 37′ N.	86° 02′ W.	L	83	58
42	April 22	Costa Rica	9° 44′ N.	85° 50′ W.	L	84	900
43	April 23	Costa Rica	8° 53′ N.	85° 07′ W.	L	84	1,000+
44	April 27	Panama	8° 26′ N.	79° 35.5′ W.	H	82	26
45	April 28-29	Panama	8° 16′ N.	80° 19′ W.	N, L	82.5	6
46	May 2	Colombia	2° 09′ N.	79° 09′ W.	H, L	79	37
47	May 3	Colombia	2° 25′ N.	79° 00′ W.	H, L	80	50
48	May 5	Ecuador	1° 16′ S.	81° 26′ W.	H, L	79	1,000+
49	May 10	Colombia	2° 00′ N.	79° 06′ W.	H	78	180
50	May 14	Ecuador	1° 37.5′ S.	81° 26.5′ W.	L	69	1,000+
51	May 15	Ecuador	1° 32′ S.	81° 43′ W.	L	77	1,000+
52	May 16	Ecuador	1° 16′ S.	81° 31′ W.	L	78	1,000+
53	May 18	Colombia	2° 09′ N.	79° 09′ W.	L	80	40
54	May 19	Colombia	2° 35′ N.	78° 53′ W.	H	80	110
55	May 21-22	Panama	8° 16′ N.	80° 19′ W.	H, N	84	5
56	May 25	Costa Rica	10° 22.5′ N.	86° 17.5′ W.	H	82	625

* H—hook and line, N—bait net, L—night light, S—stomach contents.

TABLE 2

List of Specimens Collected During Cruise of the MAYFLOWER, February 13 to June 9, 1954

Carcharhinidae—Requiem sharks
Scoliodon longurio N45(1)
Sphyrnidae—Hammerheads
Sphyrna sp. N45(1)
Dasyatidae—Stingrays
Urolophus sp. N55(1)
Clupeidae—Herrings
Ilisha furthi N25(3)
Neoopisthopterus tropicus N25(2)
Odontognathus panamensis N55(2)
Opisthonema libertate L8(1), N25(4), L26(3), L45(4), N55(1)
Opisthopterus dowi N25(7)
Clupeid larvae L5(1), L10(2), L12(13), L14(30), L20(16), L22(1), L24(2), L39(28), L40(20), L45(1), L51(2), L52(2)
Engraulidae—Anchovies
Anchoa naso N55(8)
Anchoa panamensis N25(4), N45(3)
Anchoa spinifer N25(1), N55(1)
Anchoa starksi L5(1), L26(5)
Anchoria rastralis N45(1)
Anchoriella balboae N25(5)
Cetengraulis mysticetus L5(3), N25(4), L26(2), N45(1), N55(1)
Lycengraulis poeyi N55(1)
Sternoptychidae—Lightfishes
Vinciguerria lucetia L13(27), S17(66), L18(1), L50(1)
Ariidae—Sea catfishes
Bagre panamensis N25(2), N45(1), N55(1)
Bagre pinnimaculatus N45(3), N55(1)
Bagre sp. N55(1)
Hemiramphidae—Halfbeaks
Euleptorhamphus longirostre L9(1), L36(1)
Hemiramphus saltator L12(4), L20(1), L22(2)
Hyporhamphus snyderi L5(5), N45(2), L45(14)
Hyporhamphus sp. L26(2)
Belonidae—Needlefishes
Ablennes hians pacificus L26(1), N45(1)
Belone persimilis L5(1), L26(2), L32(1)
Strongylura fodiator N45(1), N55(4)
Strongylura pacifica L28(1)
Strongylura scapularis L5(2), H19(1), N55(1)
Strongylura stolzmanni L26(3)
Strongylura sp. L14(5), L32(1)
Belonid larvae L12(3), L20(2)
Exocoetidae—Flyingfishes
Cypselurus atrisignis L52(1)
Cypselurus callopterus L22(1)
Cypselurus xenopterus L22(7), L52(1)
Exocoetidae—Continued
Danichthys rondeleti L22(1), L51(1)
Exocoetus monocirrhus L21(2), L22(6), L32(8), L51(11), L52(5)
Fodiator acutus L5(2), L12(2), L14(24), L22(18), L26(8), L39(4), L40(3), L45(1)
Oxyphorhamphus micropterus L9(17), L10(5), L13(7), L15(8), L22(46), L28(12), L29(1), L31(3), L32(13), L33(10), L35(1), L38(1), L39(1), L41(1), L43(1), L46(9), L47(1), L51(3), L52(10)
Prognichthys gibbifrons L8(1), L22(29), L28(1), L39(2), L40(2), L52(1)
Exocoetid L9(1), L10(2), L15(2)
Synodidae—Lizardfishes
Synodus scituliceps N45(2)
Synodus sp. L9(5), L10(10), L12(3), L13(14), L15(2), L20(1), L21(3), L22(1), L28(10), L31(1), L32(2), L35(3), L41(2), L42(2), L50(1), L52(4)
Myctophidae—Lanternfishes
Benthosema pterota L41(4)
Diogenichthys atlanticus L13(1)
Diogenichthys laternatus L41(2)
Gonichthys cocco L8(1), L13(5), L15(134), L16(4), L18(3), L21(12), L22(2), L28(6), L29(2), L32(4), L34(2), L46(4), L50(75), L51(32), L52(1)
Hygophum reinhardti L28(1), L29(1), L32(2)
Myctophum affine L8(12), L9(4), L10(4), L13(9), L15(4), L16(6), S17(2), L18(1), L24(11), L33(3), L43(2), L48(61), L50(38), L52(1)
Myctophum aurolaternatum L8(39), L13(6), L21(4), L22(16), L24(3), L28(9), L29(8), L33(1), L46(4)
Myctophum evermanni L22(7), L28(45), L29(12), L32(14), L33(12), L34(5), L35(4), L43(28)
Ophichthidae—Snake-eels
Ophichthus zophochir L45(1)
Echelidae—Worm-eels
Garmanichthys bicollaris L12(4)
Gadidae—Cods
Gadid S23(1)
Bregmacerotidae—Threadfin codlings
Bregmaceros bathymaster S1(2)
Holocentridae—Squirrelfishes
Myripristis occidentalis L21(1), L22(5), L24(1), L28(7), L29(3), L41(1), L42(1), L46(6)
Bothidae—Lefteyed flounders
Citharichthys platophrys N45(1)

TABLE 2—Continued

List of Specimens Collected During Cruise of the MAYFLOWER, February 13 to June 9, 1954

Bothidae—Continued
Citharichthys spilopterus N45(1)
Cyclopsetta querna N45(1)
Etropus crossotus N45(1)
Bothid larvae L10(18), L13(1), L32(1)

Soleidae—Soles
Trinectes fonsecensis N45(2), N55(1)

Cynoglossidae—Tonguefishes
Symphurus sp. N25(2), N45(1), L52(1)

Lobotidae—Tripletails
Lobotes pacificus N45(1)

Serranidae—Basses
Anthias sp. S7(22), S17(1)
Dermatolepis punctatus H19(2)
Diplectrum pacificum N45(1)
Epinephelus analogus H4(2)
Epinephelus labriformis H19(2)
Epinephelus sp. H47(1)
Hemilutjanus macropthalmos H12(1)
Paralabrax albomaculatus H12(6)
Paranthias colonus H19(2)
Serranid larvae S3(1), L10(2), L13(15), S23(3)

Apogonidae—Cardinalfishes
Apogon atradorsatus L10(1)

Centropomidae—Robalos
Centropomus robalito N45(1)

Mullidae—Goatfishes
Pseudupeneus grandisquamis S3(1), L5(1), L22(15), L24(16), L28(9)
Pseudupeneus sp. L39(6), L40(3), L46(10), L47(2), L52(1), L53(1)

Mugilidae—Mullets
Mugil sp. L5(22), L8(2), L10(21), L12(7), L13(2), L14(24), L20(53), L21(1), L22(27), L24(13), L26(2), L39(18), L40(2), L45(1), L46(6), L51(2), L53(11)

Sphyraenidae—Barracudas
Sphyraena ensis N27(2)
Sphyraena idiastes H17(2)

Polynemidae—Threadfins
Polydactylus approximans S2(6), S3(1), L22(16), L24(21), N25(5), L28(6), L39(27), L40(18), N45(4), L46(10), L47(13), L51(5), L53(5), N55(1)
Polydactylus opercularis L21(1), L22(2), L39(3), N45(15), L50(3), L51(2), L52(115), L53(2)

Nematistiidae—Roosterfishes
Nematistius pectoralis L51(1)

Carangidae—Jacks
Alectis ciliaris L22(1), L39(1), L52(5)

Carangidae—Continued
Caranx caballus L21(17), L22(96), S28(1), H36(1), L40(4), L42(4), N45(3), L47(1), L53(1)
Caranx caninus N45(3)
Caranx vinctus L21(7), L22(1), L53(4)
Caranx sp. S3(1), L52(3)
Chloroscombrus orqueta S3(3), L26(3), L39(4), L40(12), L45(5), N45(11), N55(4)
Citula dorsalis N27(2)
Decapterus sp. L10(1), L14(1), H21(1)
Elagatis bipinnulatus H17(1)
Hemicaranx leucurus N45(7), N55(1)
Hemicaranx zelotes N55(1)
Naucrates ductor L12(1), L21(1), L31(1), H36(4), L40(1), L41(1), L47(13), L52(1)
Oligoplites mundus N5(1), N45(3), N55(1)
Oligoplites refulgens N5(1), N45(20), N55(1)
Oligoplites saurus N27(2)
Oligoplites sp. L5(8), L24(12), L26(1), L51(2)
Selene brevoorti N5(1), N45(1)
Seriola colburni H49(2), H55(1)
Seriola mazatlana L8(1), L22(7)
Trachinotus paitensis L39(1)
Trachinotus sp. L12(1), L13(2), L20(3), L26(1), L40(11), L52(1)
Vomer declivifrons L5(2), N27(3), N45(1), N55(4)
Carangid larvae L10(16), L39(2), L40(6)

Stromateidae—Harvestfishes
Cubiceps sp. S7(1)
Palometa palometa N55(6)

Coryphaenidae—Dolphinfishes
Coryphaena hippurus L10(2), L13(2), L22(4), L35(1), L47(3), L53(1), H54(1), H56(15)
Coryphaena equisetis L9(1), L10(9), L21(2), L22(18), L28(2), L31(1), L32(3), L39(1), L40(1), L46(6), H48(5), H49(7), L51(1), L52(17), L53(1), H54(1)

Echeneidae—Remoras
Phtheirichthys lineatus L22(1)
Remora remora H16(1), H28(2), H38(1), H46(5)

Scombridae—Mackerels
Pneumatophorus peruanus N5(12), H9(1), H10(16)
* Scombroid larvae L10(5), L13(14), L14(1), L21(1), L28(4), L29(40), L31(5), L32(1), L33(3), L34(1).

* Scombroid larvae includes all unidentified tuna-like larvae.

TABLE 2—Continued

List of Specimens Collected During Cruise of the MAYFLOWER, February 13 to June 9, 1954

Scombridae—Continued
  Scombroid larvae—continued
    L35(2), L36(5), L37(1), L39(1), L40(6), L41(6), L42(1), L52(5)
Cybiidae—Spanish mackerels
  Sarda velox H14(1)
  Scomberomorus sierra N5(7), L39(1), L40(1), N45(5)
Katsuwonidae—Skipjacks
  Auxis thazard H11(3)
  Auxis sp. N5(3), L8(1), L9(32), L10(246), L13(351), L14(64), L15(7), L16(3), L21(419), L22(14), L24(24), L28(52), L29(14), N30(23), L31(59), L32(47), L33(22), L34(40), L35(10), L37(11), L38(24), L39(3), L41(19), L42(49), L46(11), L47(18), L48(73), L50(4), L52(43), L53(1)
  Euthynnus lineatus H49(1)
Gempylidae—Snake mackerels
  Gempylus serpens L16(1), L28(1)
  Nealotus tripes L13(1)
Trichiuridae—Cutlassfishes
  Trichiurus nitens S6(15), N25(7)
Istiophoridae—Sailfishes
  Istiophorus greyi L39(2)
Lutjanidae—Snappers
  Lutjanus peru H47(3)
Haemulidae—Grunts
  Brachydeuterus leuciscus N45(1)
  Orthopristis chalceus N55(4)
  Orthopristis lethopristis H19(1)
  Pomadasys panamensis N45(2)
Sciaenidae—Croakers
  Bairdiella chrysoleuca N55(2)
  Cynoscion phoxocephalus N25(1), N45(3)
  Cynoscion squamipinnis N25(2), N55(1)
  Isopisthus remifer N25(1), N55(2)
  Larimus acclivis N25(1)
  Larimus argenteus N55(1)
  Larimus effulgens N45(1), N55(3)
  Nebris occidentalis N25(2), N45(2), N55(3)
  Ophioscion strabo N55(5)
  Paralonchurus dumerili N45(2)
  Paralonchurus rathbuni N25(2)
  Stellifer ericymba H45(10), N55(5)
  Stellifer furthi N55(1)
  Stellifer illecebrosus N25(2), N45(1)
  Stellifer oscitans N45(2), N55(2)
Branchiostegidae—Blanquillos
  Caulolatilus princeps H17(1)
Pomacentridae—Damselfishes
  Chromis atrilobatus L24(29), L28(2), L38(1), L42(5), L46(21)

Pomacentridae—Continued
  Pomacentrid larvae L9(1), L10(1), L12(26), L13(1), L14(6), L21(11), L22(4), N28(23), L29(12), L31(1), L32(3), L33(3), L34(4), L35(3), L39(15), L40(1), L41(2), L42(18), L46(2), L47(4)
Labridae—Wrasses
  Pimelometopon darwini H12(2)
Chaetodontidae—Butterflyfishes
  Chaetodon humeralis S3(1), L28(6), L31(1), L32(5)
Kyphosidae—Rudderfishes
  Kyphosid juveniles L8(7)
Scorpaenidae—Rockfishes
  Pontinus clemensi H47(1)
  Pontinus sp. S23(65), S28(1)
Triglidae—Gurnards
  Prionotus horrens N25(23)
Fistulariidae—Coronetfishes
  Fistularia sp. L10(1), L12(1), L13(1)
Syngnathidae—Pipefishes
  Hippocampus ingens L39(1)
Gobiidae—Gobies
  Tyntlastes brevis N45(1)
Uranoscopidae—Stargazers
  Kathetostoma averruncullus S23(2)
Callionymidae—Dragonets
  Callionymids S23(17), S28(10)
Clinidae—Klipfishes
  Starksia sp. L12(5)
Blenniidae—Blennies
  Ophioblennius steindachneri L10(2), L13(3), L21(4), L32(1), L53(7)
  Runula azalea L10(43), L13(15), S28(1), L28(2)
  Blenniid larvae L10(1), L12(30), L13(2), L14(4), L20(3), L21(2), L24(1), S28(1), L45(1), L51(1), L52(4), L53(1)
Brotulidae—Brotulids
  Brotula clarkae S6(1), S23(1), S28(4)
Ophidiidae—Cusk-eels
  Ophidiids S1(1), S23(5)
Lophiidae—Anglers
  Lophius sp. S28(1)
Balistidae—Triggerfishes
  Canthidermis maculatus L22(2)
  Canthidermis sp. L21(1)
  Balistid N30(1)
Tetraodontidae—Puffers
  Lagocephalus lagocephalus L32(1)
  Sphoeroides annulatus N25(2)
  Sphoeroides furthi N45(1)
  Sphoeroides sp. L10(1)
Diodontidae—Porcupinefishes
  Diodon holacanthus L47(2)
  Diodon sp. L5(2)

ACKNOWLEDGMENTS

I wish to thank the following people for their contributions to this report: Mr. Ray Medina, Captain of the M. V. MAYFLOWER, and his crew, who furnished equipment and made this cruise a pleasure; Mr. Rae Baxter, who accompanied me on the cruise and assisted in collecting these specimens; Dr. Grace Orton for identifying many of the young flying fish; Dr. Boyd W. Walker for checking scientific names and assistance in identifying several of the specimens from the Galapagos Islands and Panama; Miss Jane Bodul, who contributed a great deal of time and effort in typing and checking data; and Mr. John E. Fitch, who suggested that this collection be made, provided vital assistance in all fish identifications, distributed the majority of the specimens, and aided materially in the preparation of this paper.

REFERENCES

Clemens, Harold B.
1955. Fishes collected in the tropical eastern Pacific, 1952-53. Calif. Fish and Game, vol. 41, no. 2, p. 161-166.

Fitch, John E.
1955. *Pontinus clemensi*, a new scorpaenid fish from the tropical eastern Pacific. Wash. Acad. Sci., Jour., vol. 45, no. 2, p. 61-64.

Hildebrand, Samuel F.
1946. A descriptive catalog of the shore fishes of Peru. U. S. Nat. Mus., Bull. 189, 530 p., 95 figs.

Meek, Seth E. and Hildebrand, Samuel F.
1923-1928. The marine fishes of Panama. Field Mus. Nat. Hist., Zool. Ser., vol. 15, 3 pts., 2,044 p.

CALCULATING THE PERCENTAGE OF KILL FROM SEX AND AGE RATIOS[1]

DAVID M. SELLECK and CHESTER M. HART
Game Management Branch
California Department of Fish and Game

Determining the percentage of a game population which has been killed by hunting or natural causes frequently is highly important in game management. Robinette (1949) and Petrides (1954) have presented methods of calculating or estimating percentages of kill from sex or age ratio information. Although useful, their methods lack desirable directness and simplicity.

Formulas or methods for calculating populations from total kill in combination with sex and age ratios have been presented by Kelker (1940, 1943), Allen (1942), Riordan (1948), Petrides (1949), Lauckhart (1950), and Dasmann (1952). These methods enable percentage of kill to be determined indirectly, by dividing the population figure obtained into the kill figure.

This paper presents formulas which are simpler and easier to use than the above methods for calculating percentage of kill. The fraction or percentage of a population killed is calculated directly from sex or age ratios in the population before and after the kill and in the kill. Total kill figures are not needed, but all ratios must be true ratios or equally biased to produce accurate results. A basic requirement is that the kill must be differential for sex or age groups, so that a change in the sex or age ratio of the population is produced as a result of the loss.

The formulas have universal application in determining percentage losses in wildlife populations from hunting, trapping, or natural causes when differential losses by sex or age groups take place and ratios in the population and in the losses can be determined. Greatest application probably will be to pheasants and to deer or other antlered game—species which lend themselves best to field identification of sex or age of individuals.

In using these formulas it must be assumed, of course, that the only source of mortality is the one being studied. That is, the results are indicative of the total mortality during the period between the two ratio measurements of the live population. If hunting mortality is calculated and there is significant natural mortality during the hunting season, the resulting estimate of hunting mortality is high.

[1] Submitted for publication May, 1957. Review of the formulas or mathematical assistance by George H. Kelker, Glenn Harry, James Iven, and various members of the California Department of Fish and Game is gratefully acknowledged.

BASIC FORMULAS

Symbols used in the basic formulas are as follows:

B = ratio in population before kill.

K = ratio in kill.

A = ratio in population after kill.

Definitions of terms used in stating the basic formulas are:

Base population—population segment used as a base in expressing ratios, as females in males per 100 females.

Ratio population—population segment expressed as a ratio figure, as males in males per 100 females.

Total population—total of base and ratio populations.

Using the above symbols and terms, the basic formulas are as follows:

1. $\frac{B - A}{K - A}$ = decimal fraction of base population killed.

2. $\frac{K(B - A)}{B(K - A)}$ = decimal fraction of ratio population killed.

Any type of ratio figures may be used in the above two formulas. A third formula, for calculating portion of total population killed, must be adjusted to the number of units in the base population expressed in the ratio.

3. When the ratio is per single unit of base population:

$$\frac{(K + 1)\ \ (B - A)}{(B + 1)\ \ (K - A)} = \text{decimal fraction of total population killed.}$$

When the ratio is per 100 units of base population:

$$\frac{(K + 100)\ \ (B - A)}{(B + 100)\ \ (K - A)} = \text{decimal fraction of total population killed.}$$

Example 1. Use With Sex Ratio Data

Following is an example calculating the percentage of population killed by use of sex ratio data. A sample population of pheasants is used, with a differential kill by sexes in hunting season.

	Numbers of pheasants			*Sex ratios*
	Cocks	*Hens*	*Total*	*(cocks/100 hens)*
Preseason population	80	100	180	80
Total hunting kill	60	20	80	300
Postseason population	20	80	100	25
Percentage killed	75	20	44	--

From the above table showing total population and kill numbers for the population in the example, it may be seen that the actual percentages of kill were 75 for cocks, 20 for hens, and 44 for the total population. For proof of the formulas, the percentages of kill will be calculated using only the sex ratio data shown in the last column in the above table, with no knowledge of total population or kill figures assumed.

In this example the method of expressing sex ratios makes hens the base population and cocks the ratio population. Values for formula symbols, or sex ratios determined from population and kill figures, are as follows:

$B = 80$
$K = 300$
$A = 25$

Applications of the basic formulas are:

1. $\dfrac{B - A}{K - A}$ = decimal fraction of hens killed.

$\dfrac{80 - 25}{300 - 25}$ = 0.20, or 20 percent of hens killed.

2. $\dfrac{K(B - A)}{B(K - A)}$ = decimal fraction of cocks killed.

$\dfrac{300\,(80 - 25)}{80(300 - 25)}$ = 0.75, or 75 percent of cocks killed.

3. $\dfrac{(K + 100)\quad(B - A)}{(B + 100)\quad(K - A)}$ = decimal fraction of total population killed.

$\dfrac{(300 + 100)\quad(\ 80 - 25)}{(\ 80 + 100)\quad(300 - 25)}$ = 0.44, or 44 percent of population killed.

The above example demonstrates the formulas to be mathematically exact. However, practical application depends upon sampling to determine representative sex ratios in the population before and after the hunting season and in the hunting season kill.

Application of this method to determine percentage killed by hunting will be easiest when both sexes are legally taken. With this condition, adequate sampling of the hunter's bag would determine the sex ratio of the total bag taken. Unless there is cause for believing otherwise, the sex ratio in the bag could be assumed to be representative of the ratio of the total kill.

In some instances males only may be taken legally, particularly with deer and pheasants. However, a realistic appraisal of the total hunting kill must recognize that some females undoubtedly are killed when males only are legal game.

Thus, the formulas presented generally are applicable when hunting regulations permit the taking of males only. However, it is more difficult to obtain the sex ratio of the kill under such conditions. If cock pheasants only are legal game, fluoroscopic examination to determine percentages of each sex carrying shot after the hunting season may provide the best indication of comparative hunting kill by sexes. In some instances, bag checks together with field searches for unrecovered dead might be used to determine the sex ratio of the total hunting kill.

Example 2. Use With Age Ratio Data

An example showing application of the basic formulas to compute population losses from age ratio information is given below. The example deals with determining percentages of winter kill in a deer herd by use of fawn adult ratios.

	Numbers of deer			Age ratios
	Fawns	*Adults*	*Total*	*(fawns/100 adults)*
Alive before winter	50	100	150	50
Winter deaths	30	20	50	150
Alive after winter	20	80	100	25
Percentage dead	60	20	33	

From data in the above table giving total population numbers and winter losses, it is evident that 60 percent of the fawns, 20 percent of the adult deer, and 33 percent of the total population died during the winter. To demonstrate use of the formulas for such conditions, these percentages of winter loss will be calculated using only the age ratios given in the last column of the above table.

In this example, adult deer are the base population and fawns the ratio population. Ratio values for symbols in the basic formulas are:

$B = 50$
$K = 150$
$A = 25$

Applications of formulas to calculate fractions or percentages of loss are:

1. $$\frac{B - A}{K - A} = \text{decimal fraction of adults dead.}$$

$$\frac{50 - 25}{150 - 25} = 0.20, \text{ or 20 percent of adults dead.}$$

2. $$\frac{K(B - A)}{B(K - A)} = \text{decimal fraction of fawns dead.}$$

$$\frac{150\ (\ 50 - 25)}{50\ (150 - 25)} = 0.60, \text{ or 60 percent of fawns dead.}$$

$$\frac{(K + 100)\quad (B - A)}{(B + 100)\quad (K - A)} = \text{decimal fraction of total population dead.}$$

$$\frac{(150 + 100)\quad (\ 50 - 25)}{(\ 50 + 100)\quad (150 - 25)} = 0.33, \text{ or 33 percent of total population dead.}$$

For such use it would be desirable, where practicable, to make herd composition counts to obtain age ratios in the herd when it entered and when it left the winter range, or at times shortly before and after the period of winter loss. Sample carcass counts would give the age ratios in the winter kill.

Variations for Practical Use

Game managers working infrequently with such procedures may have difficulty in remembering or looking up various formulas which enable the desired information to be calculated. Such individuals frequently

prefer to attempt to remember as few formulas as possible, and may prefer a system such as follows.

All percentages of kill may be calculated by use of the simplest basic formula:

$$\frac{B - A}{K - A} = \text{decimal fraction of base population killed.}$$

Also, modifying the symbols in the formula may help the worker to keep in mind the type of ratio used, which is the base population, and what the results will be.

Using a system of this type, the percentage of kill calculated in Example 1, by use of sex ratios, could be determined as follows:

1. $$\frac{B♀ - A♀}{K♀ - A♀} = \text{decimal fraction of hens killed.}$$

$$\frac{80 - 25}{300 - 25} = 0.20, \text{ or 20 percent of hens killed.}$$

The sex symbols indicate that hens are the base population, the ratios used are expressed as males per female or per 100 females, and the result is the decimal fraction of hens killed.

2. Then, $$\frac{B♂ - A♂}{K♂ - A♂} = \text{decimal fraction of cocks killed.}$$

The symbols show that males are the base population, the ratios are expressed as females per male or per 100 males, and the result is the decimal fraction of males killed. Recalculating ratios in Example 1 on the basis of females per 100 males and substituting in the above formula:

$$\frac{125 - 400}{33 - 400} = 0.75, \text{ or 75 percent of cocks killed.}$$

The negative quantity that would result from the particular ratio values presented above is changed to positive by the standard algebraic procedure of multiplying by $\frac{-1}{-1}$.

3. With the percentage kill for each sex determined, the percentage of the total population killed may be calculated by applying the sex ratio to obtain a weighted average kill. In Example 1, sex ratios before the season showed the population to consist of 44 percent cocks and 56 percent hens.

0.44 cocks $\times$ 0.75 cock loss = 0.33 of total population killed due to cock kill only.

0.56 hens $\times$ 0.20 hen loss = 0.11 of total population killed due to hen kill only.

Total, or weighted average = 0.44, or 44 percent of total population killed.

Some users may prefer to add $\times$ 100 to the formulas so that the product is a percentage figure instead of a decimal fraction. Others may prefer

to keep the formulas as simple as possible and shift the decimal point two places to convert the decimal fraction to a percentage figure, as in the examples given here.

Use for Calculating Populations

When the total kill is known, the formulas presented may also be used to calculate populations. The fraction of kill divided into the numbers killed, when both figures can be determined, gives the population number.

Use of this method is illustrated as follows, with figures from Example 1 above:

$$\frac{B♀ - A♀}{K♀ - A♀} = \text{decimal fraction of hens killed.}$$

$$\frac{80 - 25}{300 - 25} = 0.20 \text{ of hens killed.}$$

$$\frac{20 \text{ hens killed}}{0.20 \text{ of hens killed}} = 100 \text{ hens in population.}$$

Other sex or age groups of the population, and the total population, may be calculated in a similar manner by use of the formulas, or by applying population ratios to the first population segment computed.

Because the formula used is simple and comparatively easy to remember, some workers may prefer this method to the use of more detailed formulas which give the population figure directly.

Use of Other Formulas

The usual use of Kelker's (*op. cit.*) and similar formulas is to calculate population numbers from sex or age ratios in the population and the total kill. One of the main limitations in such use of the formulas is that total kill figures must be obtained—usually a difficult or impossible task—to produce accurate population figures.

Another application of formulas of this type, which evidently has not been pointed out previously, is their use to calculate percentage of kill when the kill data are incomplete but a representative sample of the kill has been obtained. This application is illustrated by use of one of Kelker's formulas, as follows:

Symbols:

b_b = ratio of males per female before hunting season.

b_a = ratio of males per female after hunting season.

K_D = kill of females.

K_B = kill of males.

$$\frac{b_a K_D - K_B}{b_a - b_b} = \text{number of females before hunting season.}$$

Substituting the total kill and sex ratios of Example 1 above in Kelker's formula:

$$\frac{(0.25 \times 20) - 60}{0.25 - 0.80} = 100 \text{ hens before season, actual population.}$$

$$\frac{20 \text{ hens killed}}{100 \text{ total hens}} = 0.20, \text{ or } 20 \text{ percent of hens killed.}$$

Assume that instead of the total kill of 60 cocks and 20 hens, only a sample of 20 birds of the total kill could be checked. If this sample was representative of the total kill, it would consist of 15 cocks and 5 hens.

Using these kill values in Kelker's formula:

$$\frac{(0.25 \times 5) - 15}{0.25 - 0.80} = 25 \text{ hens before season, sample population.}$$

$$\frac{5 \text{ hens checked}}{25 \text{ hens total}} = 0.20, \text{ or } 20 \text{ percent of hens killed.}$$

Use of the sample kill figures gave the same percentage of kill as did total kill data.

Because the kill figures used were less than the total kill, the population figure obtained was low. However, in this and similar formulas, the population figures obtained are directly proportional to the kill figures used.

Thus, if the sex ratio of the kill figures remains the same, formulas of this type will yield the same fraction, or percentage of kill, by dividing the population figure produced into the kill figure used, regardless of the numbers of kill used. Therefore, percentage of kill may be determined by use of sample kill data in such formulas.

SUMMARY

New and simplified formulas are presented for calculating percentage of kill from sex or age ratios in a population before and after a kill and in the kill. Total kill figures are not needed to calculate percentage of kill, but population numbers may be calculated by use of the formulas if the total kill is known.

Application of Kelker's formulas to calculate percentage of kill from sample kill data, without knowing the total kill, is shown.

Either type of formula may be used to calculate percentage of kill with ratio data, or population numbers with ratio data and total kill. However, the new formulas presented are simpler and believed to be easier to use and remember.

REFERENCES

Allen, Durward L.

1942. A pheasant inventory method based upon kill records and sex ratios. Seventh No. Amer. Wildl. Conf., Trans., p. 329-333.

Dasmann, Raymond F.

1952. Methods for estimating deer populations from kill data. Calif. Fish and Game, vol. 38, no. 2, p. 225-233.

Kelker, George H.

1940. Estimating deer populations by a differential hunting loss in the sexes. Utah Acad. Sci., Arts and Let., Proc., vol. 17, p. 65-69.

1943. Sex ratio equations and formulas for determining wildlife populations. Utah Acad. Sci., Arts and Let., Proc., vol. 20, p. 189-198.

Lauckhart, J. Burton

1950. Determining the big-game population from the kill. Fifteenth No. Amer. Wildl. Conf., Trans., p. 644-650.

Petrides, George A.

1949. Viewpoints on the analysis of open season sex and age ratios. Fourteenth No. Amer. Wildl. Conf., Trans., p. 391-410.

1954. Estimating the percentage kill in ringnecked pheasants and other game species. Jour. Wildl. Mangt., vol. 18, no. 3, p. 294-297.

Riordan, Laurence E.

1948. The sexing of deer and elk by airplane in Colorado. Thirteenth No. Amer. Wildl. Conf., Trans., p. 409-430.

Robinette, W. L.

1949. Winter mortality among mule deer in the Fishlake National Forest, Utah. U. S. Fish and Wildl. Serv., Spec. Sci. Rept. 65, 15 p.

NOTE

SECOND RECORD OF THE GREEN STURGEON IN SOUTHERN CALIFORNIA[1]

On April 27, 1957, a green sturgeon, *Acipenser medirostris* Ayres, 774 millimeters in total length and weighing 3 pounds 14 ounces was speared in 18 feet of water by Billy J. Walker, just north of Point Vicente, Los Angeles County, California. It was discovered swimming over a sandy bottom between small rocky reefs. The small cove in which it was taken is known locally as "Old Man's Cove".

The fish had nine shields in the dorsal row, 29 shields in the right lateral row, and 28 shields in the left lateral row. Both lateroventral rows had nine shields. The dorsal fin ray count varied from 40 to 42, depending upon whether or not the small anterior bony elements were counted. Similarly, the anal fin ray count varied from 28 to 29. The pattern was typical of that recorded for the green sturgeon, as was the placement of the four sub-rostral barbels.

The green sturgeon has previously been reported south of Monterey on one occasion (Roedel, 1941). In this instance a 7¼-pound specimen was taken between Huntington Beach and Newport Beach in a bait net set in 10 fathoms of water.

The specimen reported here has been deposited in the fish collection, Department of Zoology, University of California, Los Angeles.

REFERENCE

Roedel, P. M.

1941. A sturgeon in southern California waters. Calif. Fish and Game vol. 27, no. 3, p. 191.

—*Kenneth S. Norris, Marineland of the Pacific, Marineland, California, May, 1957.*

[1] Contribution No. 4, Marineland of the Pacific Biological Laboratory.

REVIEWS

The Physiology of Fishes. Volume I: Metabolism

Edited by Margaret E. Brown; Academic Press Inc., New York, 1957; xiv + 447 p., 84 figs., 1 plate. $12.

With the sight of this book, like that of an overdue paycheck, one instinctively exclaims, "I thought it would never get here". But here it is, the most detailed book on this subject so far published in English and probably in any language.

Although scientific investigation into the physiology of fishes has lagged behind that of other vertebrates and insects, a considerable wealth of information—scattered through periodicals published all over the world—has accumulated over the years. This volume and its companion, Volume II—Behavior (soon to be published), consist of reviews of the present state of knowledge on the various phases of fish physiology.

The impressive array of authorities and their subjects must be seen to be appreciated:

Chapter I. *Respiration*
Part 1. *The Aquatic Respiration of Fish* by F. E. J. Fry
Part 2. *Air Breathing* by G. S. Carter
Chapter II. *The Cardiovascular System* by J. C. Mott
Chapter III. *The Alimentary Canal and Digestion* by E. J. W. Barrington
Chapter IV. *Excretion and Osmoregulation* by Virginia Safford Black
Chapter V. *The Skin and Scales* by John Van Oosten
Chapter VI. *Endocrine Organs* by William S. Hoar
Chapter VII. *The Gonads and Reproduction* by William S. Hoar
Chapter VIII. *Early Development and Hatching* by Sydney Smith
Chapter IX. *Experimental Studies on Growth* by M. E. Brown
Chapter X. *The Biochemical Composition of Fish* by R. M. Love

Each chapter is a bulging sourcebook of technical information, containing, in addition, an extensive list of references of worldwide coverage. Only one, Chapter V, tenders a skimpy and wholly inadequate set of references. A fine subject and author index merits attention and praise, as do the clear and concise figures and tables.

This book performs an immeasurable service to the advancement of fisheries conservation, a field just now achieving the recognition it deserves as an important contributor to national well-being. Successes in this field ultimately depend on intimate knowledge of the behavior and reactions of each species under varying conditions. To this end, a considerable store of data on fish life histories has accumulated but concomitant studies on fish physiology, necessary for complete understanding of fisheries problems, have not kept pace. This volume compiles much of what is known on the physiology of fishes and, at the same time, indicates gaps in knowledge and possible fruitful lines for further research. Here is a new starting point for many fisheries biologists, offering many avenues of approach to complex problems.—*Almo J. Cordone, California Department of Fish and Game.*

Trout Fishing and Trout Flies

By Jim Quick; The Countryman Press, Woodstock, Vermont, 1957; 252 p. illus. $5.

This is a thoroughgoing manual on the art of trout fishing with artificials. Methods and gear are covered in detail. Jim Quick knows his trout flies and how to use them. He wisely stresses the principles behind successful fly fishing, so interested duffers should be able to improve their "luck" by digesting and applying his ideas. Good fishermen will enjoy comparing notes with an expert.

The book is readable, after you wade through four rather peculiar introductions. It is nicely put up, and generously illustrated with ink drawings by the author. There are four color plates of flies, plus three of photographs of flies and the materials used to make them. There is ample good reference material on gear and angling methods, along with tables of data on the characteristics of lines, leaders, and flies.

The brief section on trout life history and management gives the impression of an afterthought tossed in because works like this are supposed to have one.

The chapters on flies and fly-tying are particularly good.

There is a brief chapter on the much-neglected subject of sportsmen's ethics, to supplement the pleasant overtone of good sportsmanship that runs through the book. —*Alex Calhoun, California Department of Fish and Game.*

The Galathea Deep Sea Expedition

By Anton F. Bruun et al. (translated from the Danish by Reginald Spink); The Macmillan Company, New York, 1957; 296 p., illus., 1 map. $8.

During the years 1950, 1951, and 1952 the Danish research vessel GALATHEA carried out a highly successful investigation of many of the known abyssal depths of world seas. A number of the scientists who participated in the expedition describe, in this volume, the particular phases in which they played a major role. These various accounts are presented in such a smooth flowing, easy-to-read style and are so interesting that, with the turning of each successive page, it becomes increasingly difficult to set the book aside unfinished.

After the reader is acquainted with the multitude of details attendant with planning a trip such as this, he is given an insight into the pitfalls and minor disappointments which invariably crop up and cause unforeseen delays in starting on time. There follow brief accounts on the ship and her complement, the objects of the expedition, and research techniques and methods used in studying the depths of the ocean.

Considerable specific, as well as general, information is presented on many of the biological discoveries of the expedition. Data are given on people, fish, birds, snakes, invertebrates, bacteria, and plants encountered in the course of the trip, and several little-known, seldom-visited localities where stopovers were made are interestingly described.

The index, a map showing the route of the expedition, and numerous, well-chosen black-and-white illustrations add immeasurably to the value of the book.—*John E. Fitch, California Department of Fish and Game.*

Sea Treasure

By Kathleen Yerger Johnstone; Houghton Mifflin Co., Boston, 1957; xiv + 242 p., illustrated by Rudolph Freund and René Martin. $4.

The keynote of this volume is procedure—procedure in finding, cleaning, labeling, storing, trading, buying, sharing, and just about all the other vital information connected with shell collecting as a hobby. In addition, a considerable amount of basic general information on sea shells and the animals that make them has been included.

Several chapters deal with the multitude of uses to which man has put shells throughout the ages. It is pointed out how the travel and trade routes of ancient man have been determined from the kinds and numbers of sea shells left in Indian burial mounds, encampment areas, and kitchen middens. All of this information is extremely interesting and has been presented in an easy-to-read style.

The color illustrations are superb and the black-and-white drawings are exactingly portrayed. Most of the illustrations are of east coast shells but this should not deter from the value of the book to a west coaster.—*John E. Fitch, California Department of Fish and Game.*

Hawks, Owls and Wildlife

By John J. Craighead and Frank C. Craighead, Jr.; The Stackpole Company, Harrisburg, Pennsylvania, and Wildlife Management Institute, Washington, D. C., 1956; xx + 443 p., illus. $7.50.

This book is an ambitious work that covers a study of raptor predation in two study areas. The main one was Superior Township in Michigan. This area consists primarily of dairy farms and grassland. Eleven percent of it is made up of wood lots. The second study area was a semiwilderness one at Moose, Wyoming.

For two years, year-round population densities, activities, movements, mortality, and productivity of the raptor and major prey populations were determined in the Superior Township area. Similar data were gathered during the spring and summer in the area at Moose, Wyoming.

The authors believe the major contributions of the book to be:

1. A quantitative analysis of the mechanics and functions of raptor predation.
2. A comprehensive study of raptor movements, ranges, territoriality, and interspecific and intraspecific behavior as related to collective raptor populations.
3. Quantitative proof of the efficacy of raptor predation as a natural biological control or regulator, and clarification of the relationship of this phenomenon to other environmental forces that regulate the population levels of vertebrates.
4. A study of collective populations presenting a new approach to a further understanding of the forces or processes which regulate the densities of animal populations.

This book goes into great detail regarding the methods used; this will be of great value to research workers who wish to make a critical evaluation of the work, or who wish to conduct similar investigations. However, this detail does not make for easy reading.

The information presented in this book is excellent and makes possible a much better understanding of avian predation and how it functions in relation to prey populations. This book adds much specific detail on how raptors act as a natural control on prey populations and how the prey population levels in turn tend to limit the raptor population.

It is too bad the authors did not make use of some of the excellent work by David Lack in 1954. However, since the latest cited reference was dated 1953, perhaps the manuscript was completed prior to the publication of Lack's work.

In any case, this book makes a valuable contribution toward a better knowledge of a poorly understood group of animals, and their effects on game and nongame animals.—*Wallace G. Macgregor, California Department of Fish and Game.*

Animal Navigation

By J. D. Carthy; Charles Scribner's Sons, New York, 1956; 151 p., illus. $3.95.

This book is in no sense a textbook. The subject of animal navigation is reviewed, with many theories discussed at great or lesser length. But to this reviewer, at least, few questions were answered, and he was left with many more questions and doubts concerning the validity of some current navigation concepts than he had before beginning the book. This, of course, is as it should be, for this most fascinating aspect of animal behavior is yet in its struggling infancy and offers a boundless opportunity to speculate.

The scope and interest in this book may perhaps be best expressed through a consideration of chapter headings and some quotes and reviews from each.

Chapter I is entitled *Animals and Men*, and here the author sets the stage by equating animals with men in their reasons for moving to new lands.

Navigation seems to imply guidance to a goal. Many animals, particularly the smaller invertebrates, wander on, encountering the right places by chance, but the probability of finding the most favorable is increased by their inborn reactions to certain kinds of stimuli.

Chapter II, headed *Scent Trails*, develops among other things the concept of A. Forel, who considers that ants sense not only "smell", but the *shape* of a smell! The idea of an "odor arrow" assisting in the direction of ants is developed here also.

Chapter III is entitled *Home Is the Hunter* and discusses the methods by which hunting insects such as wasps find their way back to the nest. Several methods apparently are used, including memorization of landmarks from ground level and flying back; memorization from an aerial viewpoint and walking back; and climbing plants, looking around for landmarks, and then continuing on the ground to the nest.

The Nectarseekers, Chapter IV, discusses the work of Lubbock and Von Frisch concerning the sensibility of bees to color. The importance of "longness" or "richness" of outline is discussed. This chapter also reviews the famous discovery of Von Frisch relating navigation by polarized light from the sky to the bee dances by which the hive is notified of the success of a honey seeker. (Among other things, bees cannot describe height in their dance.)

The mass movements of populations are discussed in Chapter V, entitled *At the Mercy of the Elements*.

The difference in individual navigation as opposed to mass migration is emphasized. Locusts moving at the mercy of the wind are discussed. Butterfly migrations are well treated. This chapter includes a discussion of the effect of pressure of air or water on the sides of an organism in guiding animals.

The Migration of Birds. Chapter VI, contains a good review of many of the observations and speculations that have been made concerning long distance travel of birds. The fantastic long journeys of the bristle-thighed curlew and of the great shearwater are discussed, and the extreme difficulty of making a landfall in the trackless ocean is pointed out.

Chapter VII, *Aerial Navigators*, expands the previous chapter. Here the author warns against the use of the homing pigeon as an explanation of the homing behavior of all species. He calls the swallows and others true travelers.

Here is a very interesting discussion of the "internal clock" mechanism which functions in conjunction with the bird's recognition of the position of the sun, enabling it to calculate its position—a method of bio-co-ordinate navigation.

Waterways, as Chapter VIII, concerns the migrations of eels, North Sea cod, tunny, salmon, etc. There is a discussion of the recognition of a home stream by a salmon, which the author inclines to believe is due to dissolved organic substances. The influence of temperature and salinity changes, currents, inherited direction sense, magnetic field disturbances, etc., are discussed.

The built-in radar of *Gymnarchus niloticus* of West Africa and the Nile is a marvelous mechanism by means of which prey is detected through disturbance of the magnetic field surrounding the fish. The importance of this in long-range navigation is minimal.

The Fated Journey, Chapter IX, expands the earlier discussion of mass animal migrations to include the lemmings, caribou, Harp seal, whales, etc. A review of the Patuxent wild mouse trapping studies is included.

Chapter X, *Animal Senses*, contains the author's own summing up.

"It is evident that no new senses have yet been proven to exist; and, in particular, sensitivity to the earth's magnetic field has not been demonstrated.

"A difficulty which must be overcome in thinking about this problem lies in our desire, conscious or unconscious, to parallel animals' senses with our own. But willingness to admit the possibility of the superiority of animals' senses in some directions should not lead us into the realms of fantasy where so many have wandered while considering the remarkable powers of animals to navigate."

This book is heartily recommended to anyone. The author avoids highly technical discussions and writes vividly and with an excellent choice of examples. This reviewer could only wish for a more extensive bibliography, but in turn that would perhaps remove this book from the realm of general interest and make it a text suitable only for the specialist.—*Harold D. Bissell, California Department of Fish and Game.*

America's Natural Resources

Edited by Charles H. Callison; The Ronald Press Company, New York, 1957; vi + 211 p. $3.75.

Many books on the conservation of natural resources have been written in recent years. This is not just another one, but rather a brief résumé of the entire field in few words by experienced people capable of seeing the problem in its entirety.

It is a well-organized book with wide appeal. For the layman, it represents a brief and concise introduction to the fundamentals of conservation. For the professional man, it is useful as an excellent source book, summarizing the highlights of this most important problem. (Resource specialists need frequently to read books of this type to retain the proper perspective of the over-all natural resources picture.)

Edited by the Natural Resources Council of America, it brings together a clear, concise summary of the pertinent facts about America's natural resources and their conservation. Each topic, such as soil, water, wildlife, etc., is covered in a separate chapter by a leading authority in the field. These are such men as Fairfield Osborn, Shirley Allen, Albert S. Hazzard, and many other nationally known figures.

Although the chapters were prepared independently, the various authors follow a similar pattern of exposition in reviewing each resource. This is basically a description of original abundance, the impact of man's activities on the resource, modern concepts of utilization, followed by what the future holds in store. All are relatively optimistic about the future, indicating that "when man's activities are so managed that they will not be detrimental to a continued resource supply, when he has learned

to temper his demands and share in nature's benefits, then the future of our resources will be assured."

The rapid-moving text, clear type, plus change of style by each author help make up for the absence of illustrations. This is a book that will serve as an informative guide for persons wishing to take intelligent action in the defense of our natural resource heritage.—*Willis A. Evans, California Department of Fish and Game.*

The Living Sea

By John Crompton; Doubleday & Co., Inc., New York, 1957; 234 p., 24 black-and-white drawings by Denys Ovenden. $3.95.

"An exciting introduction to the sea and its creatures." These words, which appear on the dust jacket, aptly describe what the reader will find within.

The author introduces his subject with a brief discussion of the formation of the earth and its seas and the inception of life. He tells of the importance of the sea to all life and the role of plankton in its economy. He traces the evolutionary processes that enabled animals to make the land their home and follows their development through the dinosaurs to man. From here we follow the mammals as they evolve from land forms to sea dwellers, some of which, the whales, spend their entire lives at sea. Descriptions of the evolution and life history of the foregoing and many of the important fishes, mollusks, and crustaceans make very interesting reading.

The author's typically British humor adds spice to an already fascinating treatment of a fascinating subject. Mr. Crompton's recognition and forceful expression of man's destructive effects on animal populations are indeed welcome.

There are a few errors, but they detract little from the value of the book. In the reviewer's opinion, "The Living Sea" would prove absorbing and informative reading to almost anyone.—*John L. Baxter, California Department of Fish and Game.*

INDEX TO VOLUME 43

T

V

W

printed in CALIFORNIA STATE PRINTING OFFICE
59164 7-57 5200